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THE JOURNAL OF THE AMERICAN WELDING SOCIETY PUBLISHED FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING

The Welding Journal

Featuring New Welding Developments
18th Annual Meeting and
Welding Exposition
American Welding Society

VOLUME 16 OCTOBER 1937 NUMBER 10

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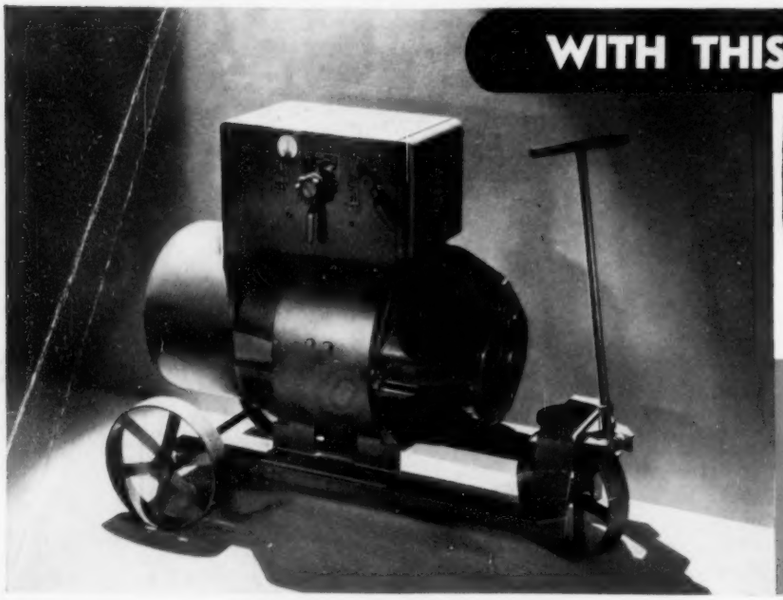

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PROGRAM AND INDEX

ANNUAL MEETING PAPERS
AMERICAN WELDING SOCIETY

SUNDAY, OCTOBER 17TH

5 to 7 P.M. Stratosphere Room, Hotel Traymore

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MONDAY, OCTOBER 18TH

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NO TECHNICAL SESSIONS OR FUNCTIONS SCHEDULED

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ISSUED MONTHLY

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Vol. 16, No. 10 **Oct. 1937**

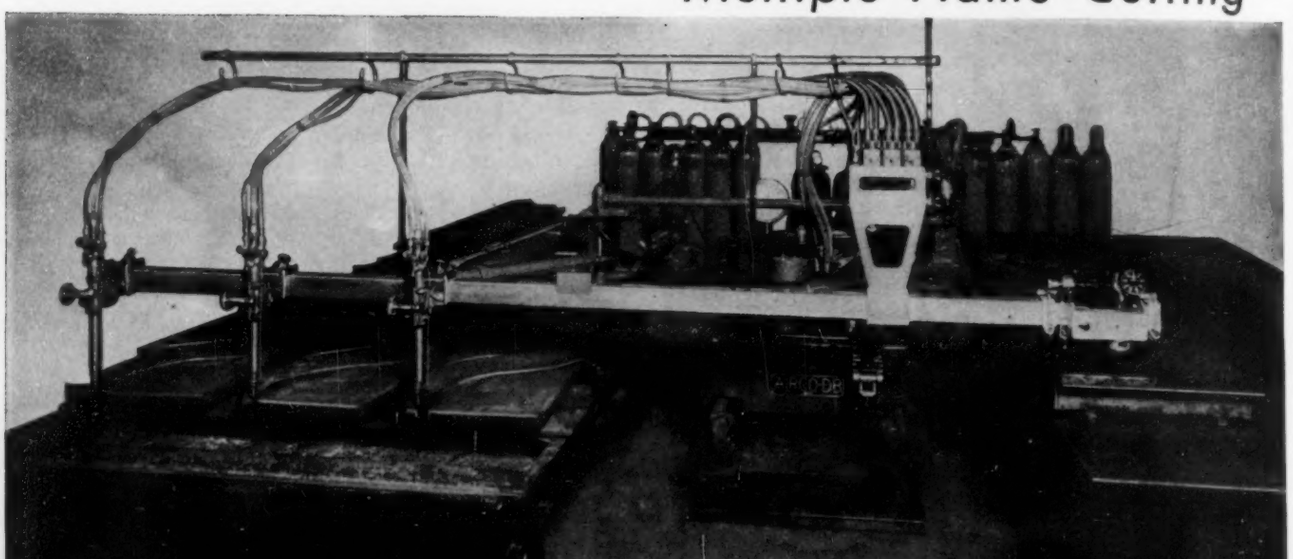
W. Sparagen, Editor

See these machines at the Nation

NEW

The AIRCO-DB TRAVOGRAPHS

Broadening the range of Multiple Flame Cutting



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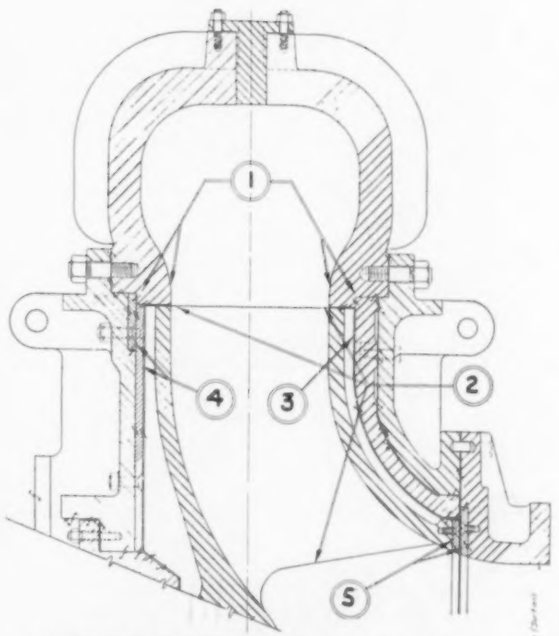
Welding—An Aid in Dam Construction*

By T. B. JEFFERSON†

WELDING as a tool of construction is usually thought of in connection with the fabrication and installation of permanent equipment. For this reason the title of this paper might lead one to believe that it is to be about one of the five steel-faced dams which have been built in Colorado. In these dams welding has played a very important part in the making of their faces into one solid water tight steel plate. On other dams welding has proved to be equally as important in the fabrication of penstocks, pipelines, tanks, buildings and numerous other items necessary to the completion of such projects.

While the use of welding as a fabricating tool has assumed a position of prominence in the construction world the equally important application of welding for the repair and maintenance of construction plant has been much less obtrusive. That the development in this field is almost as great as in the field of permanent installations is clearly shown from experiences at the Fort Peck Dam.

At Fort Peck, in Northeastern Montana, where the Army Engineers are building a 100,000,000 cubic yard earth-fill dam across the Missouri River, welding for maintenance is playing an important rôle. On this huge but isolated project, far from sources of supplies and repairs, the engineers have had to provide a means of keeping a vast array of heavy equipment in operation despite inevitable breakdowns and wear resulting from handling highly abrasive material. Welding was naturally one of the means the engineers used. An idea of its importance to the project may be gained from the fact that at the peak of construction 423 men were employed as welders. All of these welders were required to pass qualification tests proving them capable of producing welds



SECTION THRU PUMP SHOWING ORIGINAL CASE AND LINERS WITH POINTS OF GREATEST WEAR SHOWN

Fig. 1

Fig. 2—Typical Worn Condition of a Pump Casing Needing Repair

* To be presented at Annual Meeting, AMERICAN WELDING SOCIETY, Atlantic City, October 18–22, 1937.

† Associate Engineer, U. S. Engineer Department.

showing good welding and high physical characteristics. These test welds must be capable of withstanding an average tensile stress of more than 60,000 lb. per square inch, for the three weld positions, that is, flat, horizontal and overhead.

Thus, through necessity the welding operations in connection with an undertaking of this nature became those of maintenance rather than fabrication.

These maintenance problems were not of the type that could be solved by the mere replacing of lost metal or the welding of cracks, etc., but in nearly every case they represented a problem in welding engineering which heretofore had been classed as one that "can't be done." Due to the variety of work to be performed and the inability to obtain authoritative information regarding the problems at hand it was decided to make extensive studies of the existing conditions so that welding procedures most suitable to the repairs to be undertaken could be devised.

These studies and later observations under working conditions developed the specific uses to which either the oxyacetylene or the electric arc processes of welding could be applied. Practical tests proved that there were a number of gas welding rods of commercial manufacture with the desired physical and welding characteristics for the proposed work, thus these rods presented no particular difficulty. For electric welding it was readily determined that the heavily coated electrode, in most cases, was far superior to either the bare, dust or rust coated electrode. However, it was difficult to find a coated electrode that possessed all of the characteristics desirable and necessary for good welding. It was not infrequent that tests proved that an electrode which would produce a weld of high tensile strength also produced a weld which was lacking in ductility. In other cases the deposit would be porous because of gas inclusion, the fusion improper because of poor penetration, and oxidation and splattering would result because of improper shielding.

While most of the tests conducted to determine suitable filler rods for welding were of a practical nature, the engineering laboratory on the project rendered considerable assistance in the selection of the proper welding rod since it was equipped to make complete physical tests. With the aid of this equipment it was possible to determine all the physical characteristics of the rods and their weld specimens. Likewise it was also possible to make microscopic and macroscopic examinations of weld deposits. The information obtained in the laboratory coupled with the practical tests in the shop soon proved that very few commercial electrodes would fulfill the necessary requirements for a suitable welding electrode.

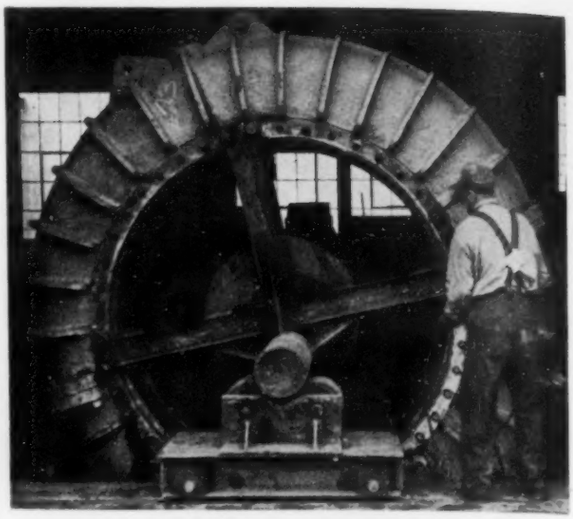


Fig. 3—Fitting Pump Case to Facilitate Repair

The maintenance problems were similar to those confronting every one engaged in construction work particularly those using heavy excavating machinery. In the moving of the large quantities of material required for this massive earthen structure nearly every known type of excavating machine is in use; there are dredges with their pumps, impellers and cutters, draglines, shovels, dozer-equipped tractors, scrapers, graders and similar machines. In each, the maintenance problem is that of combating wear—wear caused by impact, abrasion and corrosion. That part of the equipment which has been worn away is replaced by welding and an attempt is made to increase its wearing life by an application of a thin surfacing material which will impart to the rebuilt piece a greater wear resistant quality.

Here again considerable research was involved in an effort to determine the correct material to use for an overlay so that the efficiency of a part so treated would not only be increased, but also its life would be prolonged by the increasing of its wear resisting ability. Since little is known about the abrasion resistant characteristics of materials under different conditions and as no satisfactory method has been developed for determining this characteristic, practical tests were conducted by subjecting the materials to actual working conditions. Most of the commercial hard facing materials were tested and other tests were run on softer materials including bronze

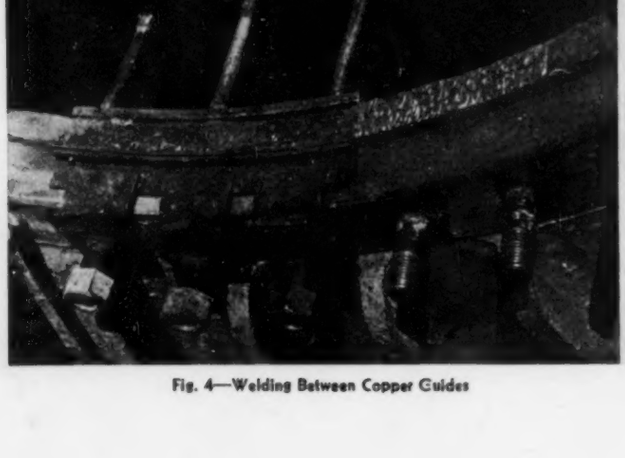


Fig. 4—Welding Between Copper Guides

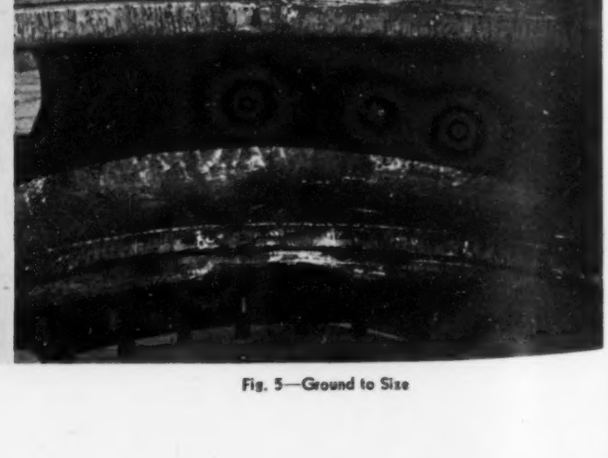


Fig. 5—Ground to Size

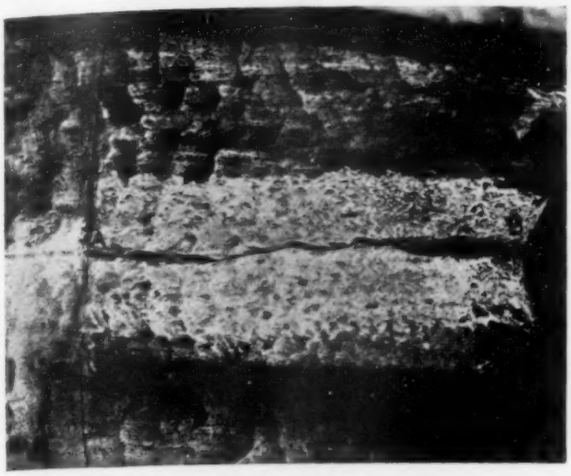


Fig. 6—Cracks in Throat Section of Pump

and lead. All were found to possess certain abrasion resistant qualities though a majority of the materials were not suited for the proposed uses.

Inasmuch as all of the material required in the building of the Fort Peck Dam is being placed by dredges a major portion of the maintenance work is in connection with this class of equipment. Principally the repairing of the 28-inch dredge pumps, impellers and cutters; yet because of the size, shape and the fact that these objects were made of cast steel, considerable doubt as to whether they could be reclaimed was expressed And rightly so, when you consider that the welding problem in connection with the reclaiming of the pump casing was more than that of merely replacing the metal which had been worn away with weld metal. While the replacing of the worn metal was the desired objective it must be consummated in a manner which would not result in damage to the pump case It was necessary to rebuild by welding these thick walled cast steel objects so that their machined faces would not be distorted more than $^1/_{16}$ inch during the reclaiming process. Considering the ease with which cast steel is warped when heated this would appear to be an impossible task but it was the task at hand.

The casings of these pumps which are made of a medium carbon cast steel, in accordance with A.S.T.M. A27–24 Specification, are approximately 13 feet in diameter and weigh 18 tons each. The wall thickness of the casing varies from $2^3/_4$ to $5^1/_2$ inches. The impellers which are 6 ft. 6 in. in diameter weigh 4 tons and are made of a similar medium carbon cast steel material.

Both of these items are subjected to the severest of operating conditions and are rapidly worn away because of the erosive action of the silt ladened waters which are forced through the pumps at pressures up to 300 pounds per square inch and at nominal pipeline velocities up to 25 feet per second. This scouring action coupled with the rubbing and grinding imposed by sharp quartz sand, gravel and other abrasive materials passing through the pumps necessitates the replacements of all pump parts from the standpoint of economical repair after approximately 1,000,000 cubic yards of material have been pumped.

Figure 1 pictures the 5 points of severest wear in a dredge pump: (1) The shoulder section of the pump is the point in the casing subjected to the greatest wear; (2) the points of wear on the impeller, the periphery and the ends of the vanes of the impeller are subjected to an erosive wear similar to that of the pump casing, while the entrance of the vanes are battered away by continual impact wear; (3) the front liner is next in severity of wear followed by; (4) the back liner; and (5) the impeller mouth and manhole section liners. Welding was originally used as a means of reclaiming the first three items since all were cast steel but for reasons which will be discussed later was discontinued on the front head liner. On the back head liner, manhole section liner and impeller mouth liner very little welding was attempted since these rolled steel parts could be easily and inexpensively procured. However, when these liners were abraded to such an extent as to have worn through to their supporting member whether it was back head, impeller or the manhole section the supporting member was readily repaired. The typical worn condition of a pump casing after 1,100,000 yards of material has been pumped is shown in Fig. 2. It will be noted that the shoulder sections of the pump have been abraded to such an extent that they are nearly completely worn away.

When a pump case is to be rebuilt it is taken to the larger of the project's two welding shops. Since much of the work to be done calls for the rebuilding and refacing of heavy equipment the larger, or main, shop was designed in a manner to facilitate the handling of this type of work. Because of this it is probably the most interesting of its kind in the country and unique in many of its handling methods. In one portion of the shop most of the floor space is taken up by two long pits, about four feet wide and four feet deep. These pits are the outstanding feature of the shop. On both sides of each pit there is a narrow gage railroad upon which special built jigs, with self-contained wheels, or jigs that have been mounted on small welded steel flat cars, may travel. When not in use the pits are covered with planking providing this portion of the shop with a wooden floor making it possible to carry on other activities than those for which the shop was especially designed.

All of the jigs used have been designed and built in the shop and are of all-welded construction as far as practical. They are so arranged as to place the work in the most convenient position for the welder. The jigs,

Fig. 7—Temperature Changes Cause Cracks in Pump Casing Which Are Repaired by Welding

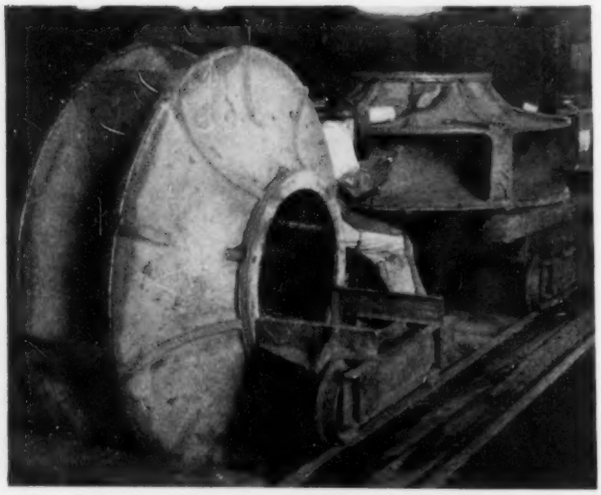


Fig. 8—Repairing Pump Impeller in a Jig

aided by the pits, allow many of the objects to be rebuilt to be placed in the least awkward working positions.

Once a pump case is brought to the shop for repairs it is fitted with an axle and spoke type jig making a large wheel with the case as a rim. The case so fitted is then suspended in one of the floor pits by resting the axle, which is set off center to obtain balance, on dollies which are supported by flat cars located on opposite sides of the pit (Fig. 3). With the pump case so arranged its lower section is below the level of the floor making the work easily accessible to the welder. Due to the construction of the jig it can be rotated at will, resulting in that part of the case on which the work is to be performed always being at the bottom so that the flat position in welding may be used extensively.

In order that the shoulders may be rebuilt with a minimum of grinding, all welding is done between copper guides (Fig. 4). Likewise, the height of the weld metal is controlled to within $^1/_{16}$ inch by means of special gages. Also, to eliminate any unnatural stresses which might be caused by welding on the pump cases or on any other piece where one bead is applied over another, the work is stress-relieved. This is accomplished by using an air operated chipping hammer to thoroughly peen each successive layer of weld metal.

When the shoulders are built up to within approximately $^1/_4$ inch of their finished height they are ready for hard-facing. Considerable care must be exercised during this operation to avoid the formation of blowholes, roughness or other conditions that might permit the abrasive materials pumped to cut away the base metals, thus, allowing the hard facing materials to be undermined and floated off before it has served its purpose. After the shoulders have been rebuilt the jig is removed and the pump case is placed on its side on two of the small flat cars, the cars being on opposite sides of one of the pits. With the case so placed the welder begins building up the side walls of the casing, and as soon as the worn places on one side are filled the case is turned over for the rebuilding of the other side. This is done so that the welders might work in the flat position as much as possible, as it is a known fact that a welder can produce a better class of work considerably faster when welding flat than in any other welding position. Upon the completion of the welding the case is ground to size (Fig. 5) and is then ready for service after three weeks of steady rebuilding work. During this time welding has replaced, on an average, 1100 pounds of metal which has been worn away from the pump case. On occasions as much as 2600 pounds of weld metal have been deposited in the casing during the rebuilding procedure.

While the repairing of the damages of erosion and abrasion constitutes a major portion of the so-called "impossible" welding that is accomplished on these castings internal stresses have brought about even more difficult welding problems. In Fig. 6 may be seen a crack in the throat section of the pump casing resulting from sand inclusion and internal stresses in the case caused by improper foundry and annealing practices during manufacture. This crack, which was 26 inches long and extended through the case which varies in thickness from $3^1/_4$ inches to $7^1/_2$ inches between points A and B, re-

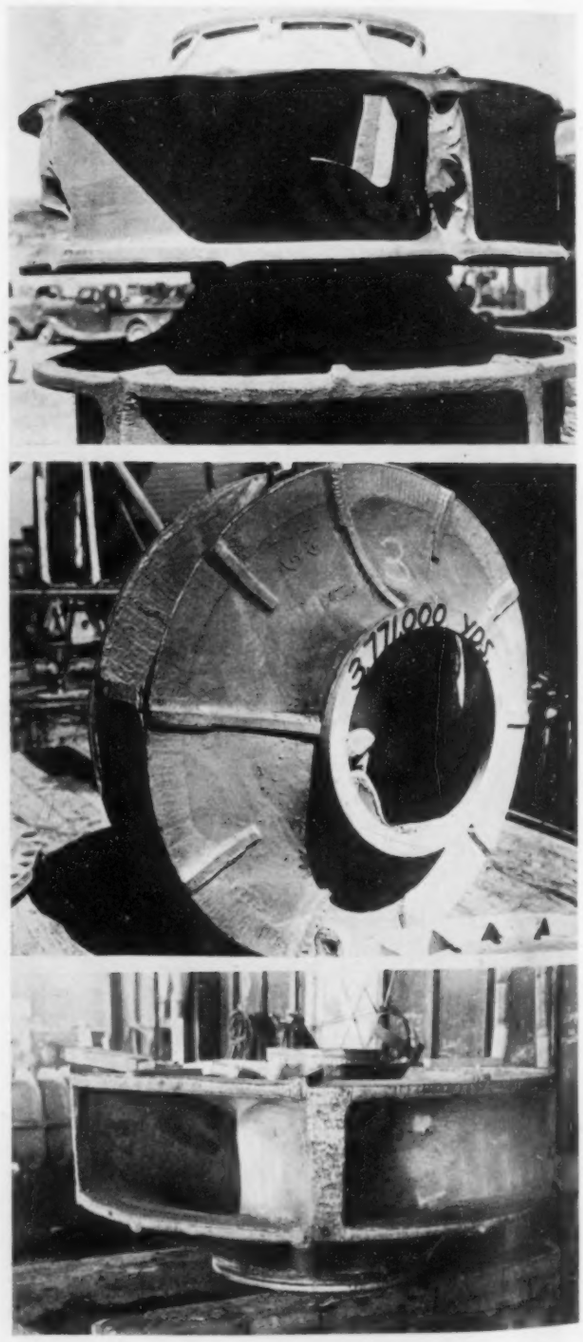


Fig. 9 (Top)—Erosive Wear on Ends of Vanes and Shrouds of Impeller. (Center)—Entrance of Impeller Vanes Battered Away by Impact Wear. (Bottom)—Reconditioned Impeller

Fig. 10
Fig. 11.

spectively, was successfully repaired. Faulty foundry practice is only one of the reasons for pump failures of this nature on the project. Other cracks were caused by the extreme temperature changes experienced in this locality. The effects of the contraction of metal through 170 degrees change of temperature, that is, from 113° F. to −60° F., are shown in Fig. 7. Each of the marks represent a crack—there were seven in all in this casing.

In every instance the cracked pump cases were repaired as though it was merely a matter of making a single or double "V" butt weld, depending upon the accessibility after the crack had been veed out. The secret of the procedure rested in the fact that the entire cross section of the casing in the vicinity was thoroughly preheated prior to the beginning of the welding operation and maintained at a temperature of approximately 800° F. during the entire welding process. The heating was carried out by using several large gas torches.

Some of these pump cases have been reclaimed by the application of weld metal and hard-facing as many as seven times without any loss in pumping efficiency as compared to a new pump. In addition, the rebuilt cases have better wear resisting qualities and are giving better service than new ones.

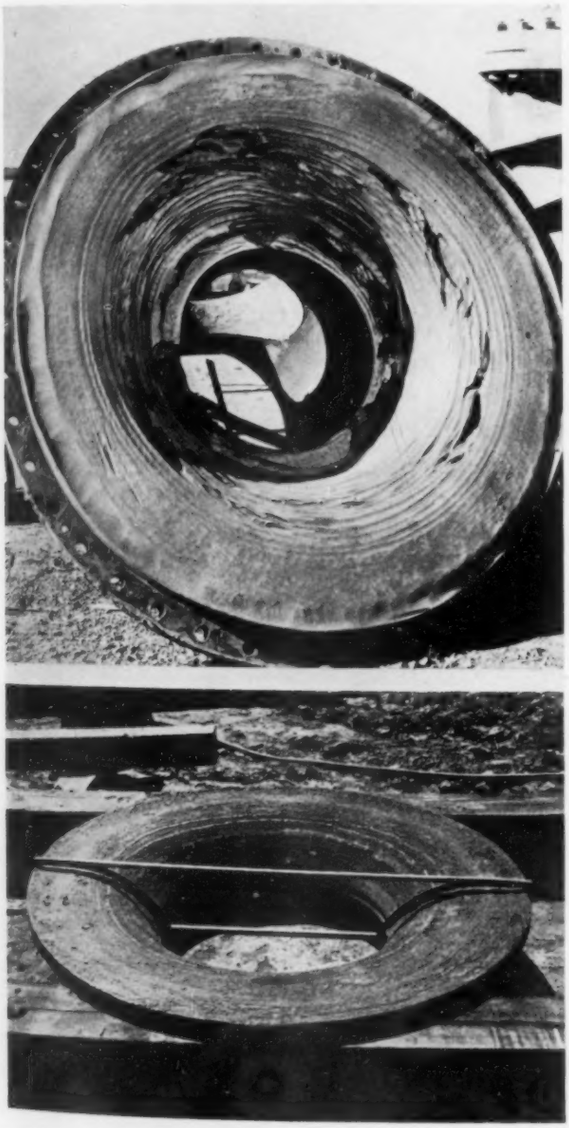


Fig. 12 (Top)—Abraded Cast Steel Liner. Fig. 13 (Bottom)—Liner Reconditioned

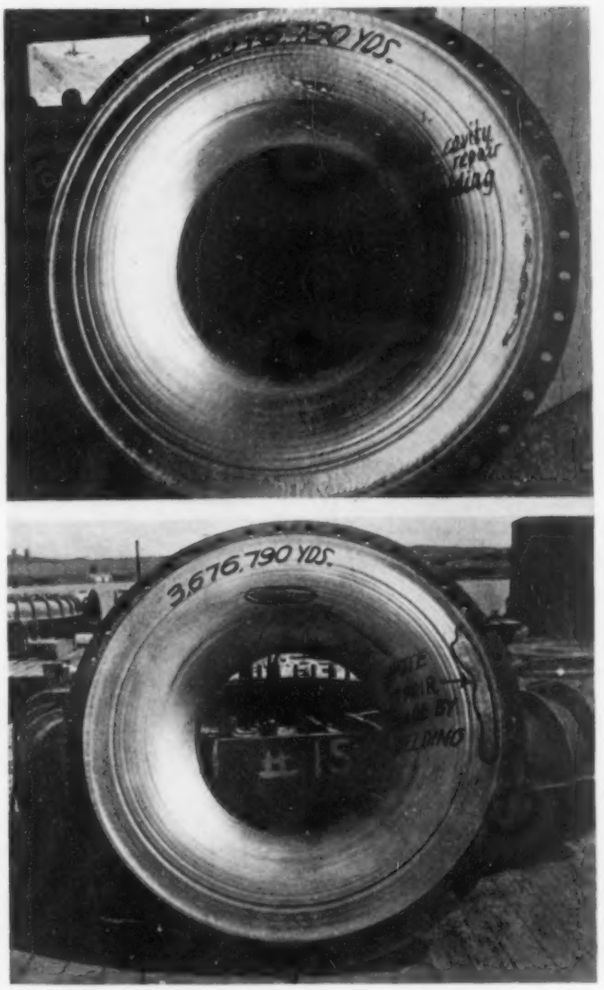


Fig. 14 and 15—Chrome Cast-Iron Liner Before and After Repair

The pump impellers are also rebuilt in a jig (Fig. 8) which permits their being rotated so that most of the welding can be done in the flat position. The jig used is mounted on wheels and travels along the rails besides the pits; the center section being dropped to accommodate the impeller. This arrangement lowers the impellers into the pits enough to bring the top to within easy reach, so that a workman can do all of the welding at this point by rotating the impeller. About the only precaution to be taken in rebuilding an impeller is to be sure the procedure is correct. Since there is little danger of warpage a major portion of the task consists merely of replacing that metal which has been lost by wear. Most of the rebuilding is of a hard-facing nature, with care being taken to lay the deposited metal at right angles to the direction of flow rather than parallel with it. Beads deposited crosswise tend to resist the erosive action of water flowing at high velocities, while beads deposited parallel to the flow permit wear to take place at the junction of the beads which soon results in greater wear than would otherwise occur.

As in the rebuilding of the pump casings the height of the weld metal deposited on the impeller is carefully governed by means of copper guide strips. The diameter of the impeller is also frequently checked by means of a "sweep" height gage.

Figure 9 pictures the effects of the erosive wear which

is experienced on the ends of the vanes and the shrouds of the impeller. In Fig. 10 may be seen the manner in which the entrance of the impeller vanes are battered away by impact wear. A completely reconditioned impeller is shown in Fig. 11.

The third point of severe wear in the pump, the front liner, is another spot in which welding is used as a means of checking wear. Originally it was used in reclaiming cast steel liners which had been abraded as is the liner in Fig. 12. In making these repairs the cavities and holes were filled with weld metal and then the entire face of the liner was returned to its original height by an application of hardfacing as may be seen in Fig. 13. The hard-facing of this liner would have been an ideal job for an automatic welding head operating on a radius arm, but before this equipment was developed liners made of a more abrasion resistant material were adopted. However, even these 25% chrome-cast iron liners require welding, Fig. 14, and Fig. 15 show the results of a job well done.

The cutter on the dredge is likewise subjected to severe abrasive wear for it must loosen all of the material that is to be later handled by the dredge pumps. A worn cutter which will soon be reclaimed by welding may be seen in Fig. 16. Also, note the unusual jig for handling these nine ton objects. As in the case of the other jigs the cutter may be moved about the shop on the small car running parallel to the pits and the cutter may be rotated at will so that most of the welding is in the flat position. A guide, Fig. 17, showing the original outline of the blade quickly determines the amount of metal loss by abrasion. This five-bladed basket type cutter is made entirely of medium carbon cast steel. It is 8 ft. 8 in. in diameter and the blades have a 14-foot cutting edge. The rebuilding and the hard-facing of a dredge cutter blade—the blade is the only part of the cutter which is subjected to severe wear—or the lips and teeth of other excavating equipment, involves much the same problem. In either of these items the method of application of hard-facing varies according to the type of material which is to be excavated. If the equipment is to work in compact abrasive material, the hard-facing may be applied in a manner to assist in the work of keeping the cutting edges sharp until they become so badly worn that their replacement becomes necessary. The cutter blades may be made self sharpening by applying the hard-facing on the front or inside face of the blade. This application allows the base metal on the back of the blades to wear away faster than the front, always keeping sharp the parts so treated. If the hard-facing material should be applied in a reverse manner the edge would quickly become so blunt as to be useless after only a short working period.

If the cutter is to be used in loose abrasive materials such as sand and gravel, tests proved that hard-facing should be applied on both the front and back sides as well as along the cutting edge. This will make the cutting edge more or less blunt, but highly abrasion resistant. The cutters in use on this project have all been hard-faced in this manner as will be seen in Fig. 18.

One of the most unusual welding jobs performed at Fort Peck was the successful repairing of four broken dredge spuds. The spuds, or anchor legs, when in use are suspended vertically from the rear of the dredge in such a manner that they may be raised or lowered vertically by the dredge operator. When digging, one spud is lowered and the point becomes embedded in the mud and sand of the river bed, securely anchoring the dredge but still permitting it to pivot about the spud. During one dredging season four spuds were broken and unless they could be repaired immediately there was the possibility of a costly shutdown should another spud be broken, as there were no replacements on hand. Also, if successful repairs could be effected, several thousand dollars of replacement expenditure could be saved.

The spuds are made of cast steel in the form of a long hollow cylinder pointed at one end as seen in Fig. 19. They are 75 feet long, 32 inches in diameter and weigh 27 tons. The wall thickness varies from $1\frac{1}{2}$ inches at the pointed end to 3 inches at the top. Because of their unusual size and shape and the fact they they must be

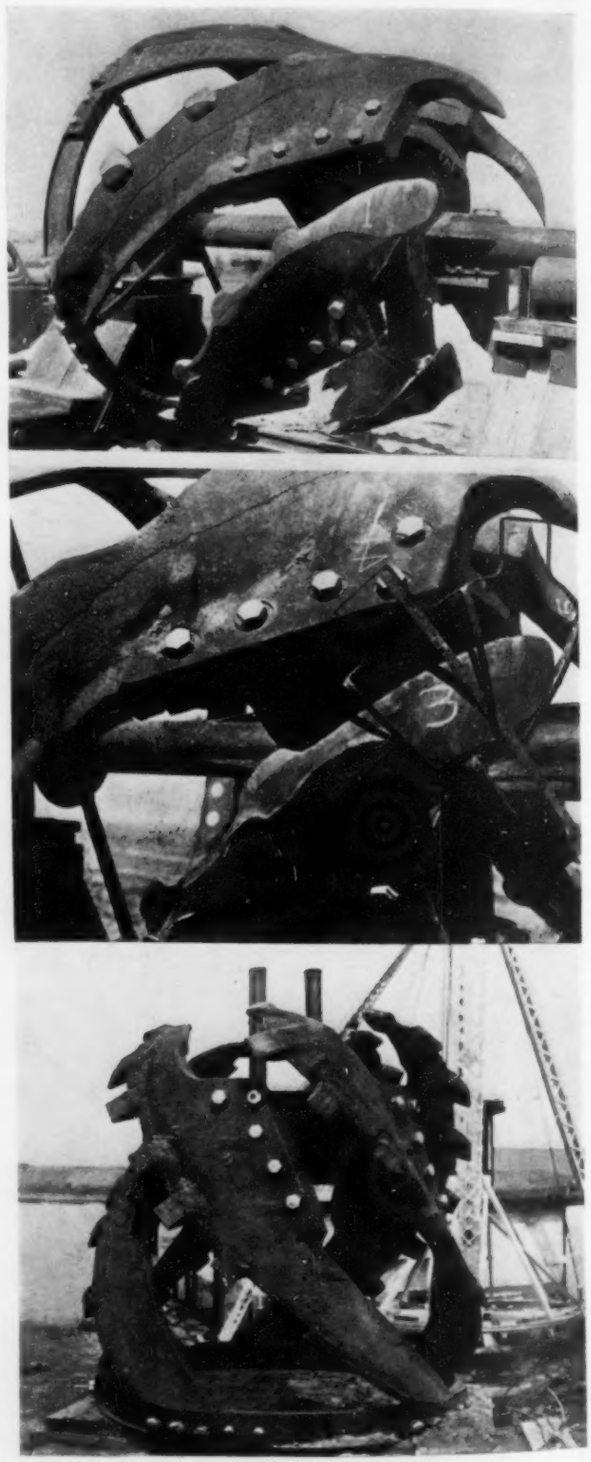


Fig 16 (Top)—Cutter in Need of Repair. Fig. 17 (Center)—Guide Showing Outline of Original Blade. Fig. 18 (Bottom)—Blade After Hard-Facing

Fig. 19—Spud Used in Connection with Dredge Operation

within 1/4 inch of plumb, a nearly impossible tolerance when welding a cast-steel object of this length, a most difficult task was at hand.

To effect these repairs it was first necessary to bevel the fractured edges of the spud just as though they were pipe ends to be joined by butt welding. The broken sections were placed on skids, the skids being of sufficient length to permit the rotation of the spud during the repair operation. After being accurately aligned the beveled ends were clamped into position by means of four sets of bolts and angle clips; the clips having previously been welded to the spud on opposite sides of the break. The spud was then tack welded. Figure 20 pictures the beveled edges of the fracture with one of the clamps ready to be welded in place. By using the electric arc process and two workmen—one welding opposite the other—the heat expansion was nearly balanced and a crooked spud avoided. Through this simple procedure requiring 175 pounds of electrode a hard job became an easy one and the repairs were successfully completed.

The maintaining of 70,000 feet of 28-inch steel pipe-line, most of which has a 3/4 inch-wall thickness, used in carrying the dredged material to the fill is another of the big and continuous welding jobs on the project. However, with the exception of making special fittings, the welding differs little from routine pipe-line or shop welding.

While the work described above represents a major portion of the welding shop's operations, the maintenance of equipment is not the only use to which welding has been employed advantageously at Fort Peck. Frequently the shop is called upon to duplicate an intricate casting or other broken part using only structural shapes and plates that are obtainable from the shop's steel yard. Usually these pieces are fabricated immediately, thereby eliminating the necessity of ordering a renewal part, and also preventing days of delay that would have been caused by awaiting the delivery of some such part from a far away factory.

The diversity of the work which is undertaken on the project occasionally calls for the fabrication of a special item of equipment which has been designed for a particular job. Again the problem may be that of rebuilding some piece of equipment at hand so that it will be suited for work of a different nature. Whichever is the case it will be found that welding has been used extensively throughout the fabricating process.

Some of the items of equipment which have been designed for special jobs and which are of all-welded construction include: A clamping device for pulling piles; a combination jet and tong for reclaiming buried piping; cable reels and numerous similar devices.

Some of the welding fabrications of the shop are undertaken because they may be performed more satisfactorily on the project than elsewhere. This is particularly true of the special fittings used on the pipe-lines. The pipe-line wyes, elbows, reducers and gate valves as well as special lengths of pipe are usually needed in a hurry and the easiest means of obtaining these items in the quickest possible manner is by welding.

Other fabrications have been undertaken because welding has been found the least expensive method of manufacture. One of the best examples of this is found in the production of sand traps for shutter, or "pocket," pipes used in the levees on the fill. These sand traps originally consisted of a cast-steel framework, which is welded to the bottom of the pipe, holding a small sliding door which may be moved at will. The movement of the door either opens or closes an opening in the pipe. However, it was found that the entire sand trap unit could be built by welding for one-half the cost of the original cast-steel unit.

Of all of the welding that has been undertaken at Fort Peck that which was performed in connection with the building of the four diversion tunnels may be classed

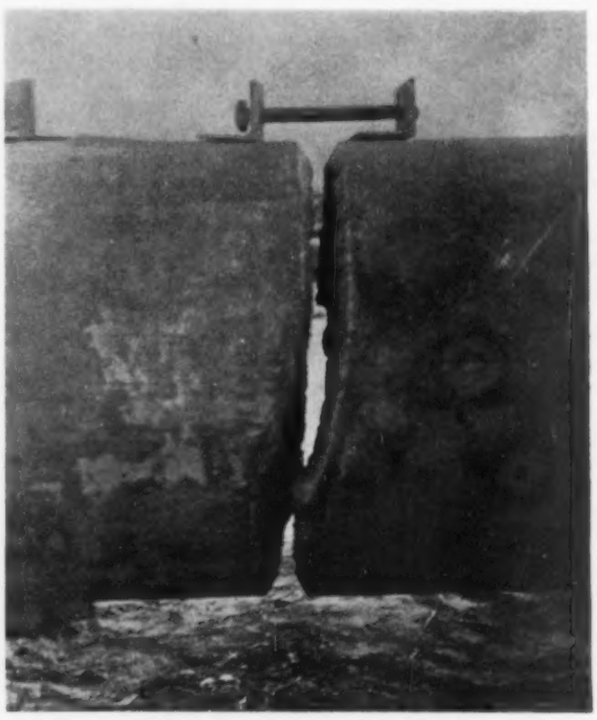


Fig. 20—Preparing Broken Spud for Welding

as fabrication for construction. In these 24 ft. 8 in. diameter concrete lined tubes which have an average length of 6323 feet there is 635,000 lineal feet of welding. Most of this welding was required in the construction of the structural steel framework of these tunnels.

Each tunnel is served by a 54 foot diameter main shaft and a two compartment emergency shaft, both of which are of an all-welded steel lined construction. All of the shaft structures, which extend vertically 197 feet above the top of the tunnel, are built of steel plates. The plates varied in thickness from $1^1/_8$ inch at the base to $^5/_8$ of an inch at the top. Each plate was welded to its adjoining plate by means of a 60° "V" butt welded so that the entire structure became a single water tight plate. Inasmuch as these structures were vertical the welder had opportunities to weld in all positions during their construction. In all, more than 325 tons of welding rod were used in the construction of the tunnels and their shafts.

Another place in which welding played an important part in the construction of the Fort Peck Dam is in the construction of the core wall. This job included approximately 50,000 lineal feet of welding on $^3/_8$-inch sheet steel piling. The welding involved was rather unusual because of its difficult nature. A major portion of the welding was in the horizontal position and was done by welders seated in boatswain's chairs suspended from the pile driving gantry. Approximately 50 per cent of this welding was done by the pile driving contractor with the remainder being completed by the crews of the Engineer Shops.

Thus, through the aforementioned problems, unusual and routine welding tasks, it may be seen briefly the manner in which welding is aiding in the construction of the world's largest earth filled dam, the Fort Peck Dam.

Likewise it has been the aim of this paper to point out the possibilities of welding not as a tool for fabrication but rather as one of maintenance. To further carry out this idea a few specific examples have been cited in which welding has been used for this purpose and as a result has not only saved considerable time in effecting the repairs, but has proved itself to be the most effective means of accomplishing the task.

Automatic Resistance Welding*

By HARRY LANDSTROM†

THE increasing demand of special alloys to fit the present-day needs forces the use of automatic welding in one form or another. Without this automatic phase of welding we could not hope for consistant welds and keep the metal in its original condition. As an example of what is demanded, let us take stainless steel. This metal is stainless only when the heat ranges are kept in bound, otherwise it changes its characteristics and becomes a good rusting steel and loses its high-strength value.

Factors Involved

Many factors enter into the welding problem beside the automatic timing. To accomplish the complete cycle such items as welding projections, or bosses, have been developed and such a seemingly unimportant item, but highly important factor, as water enters into the picture. The use of special alloys for dies and points have entered into this picture and without these all efforts would be in vain.

In the projection field where many spots are to be placed at a definite spacing, and all spots set at one time, dies are constructed to allow easy assembling of parts and here the special alloys play an important part and the projections localize the heat for spot welding. Though this method demands high kva. input, timing must be accurate to get consistant results.

Design of Projections

Even though the foregoing were carried out to a very fine degree the results would be lost if the design and uniformity of the projections were not held. These projections must be so designed and held as not to allow any shear or too much coining of metal at any point. If either of these take place the resistance at that point will cause the metal to blow out before any heat is developed into the two sheets to be welded, thereby voiding the action of good timing on weld.

No set of rules, applicable to all classes of work, governing the size and height of these bosses has been devised, but no matter the size, the above points must be adhered to. With the use of projections many heavy gage metal pieces are welded that would be impossible to spot weld with just spot welder points, either singly or in multiple.

The use of special alloys here allows the process to be repeated time after time because the die metal does not change readily and can be likened to a punch press die. The die must be dressed when the wear becomes excessive or when the wear demands a change in the automatic setting. Here in most cases water is used for internal cooling of the dies by allowing the flow to come as close as possible to the heated section without diminishing the strength of die. Rarely is water used to flow externally on the die and work.

Flash Welding

In butt or flash welding the use of alloys for dies is

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† Nash-Kelvinator Corp.

highly important and the timing takes significance only in its direct relationship of push up to the electrical cut off. Here the exactness is governed by the speed of flashing and the amount of stock used in the flashing operation. Where dies are made of hard alloys consistant results may be had as the hard surfaces do not have the tendency to wear from exerted pressures, thereby changing the characteristics of the set up.

With automatic timing the human element is voided, thereby the machine will repeat the same quality of weld. The dies, in many cases, and especially the lighter gages of sheet metal, must be fitted to the part and clamp the work tightly at all places. This will allow metal to be butted in alignment and hold the heated area between the jaws, preventing any heat to saturate under jaws and cause distortion. Many such dies are "spotted" into the work and if metal in dies is not tough enough to stand the constant clamping, heat distortion will soon set in, which will change the automatic setting.

Seam Welding

The art of automatic welding reaches its greatest height in seam welding. In this branch of resistance welding the automatic features determine the quality and speed of welding. Here any one of several factors may make or ruin the weld and also govern how fast good welds can be produced. A good welder, with the best of welding transformers, can be ruined by the use of poor seam welder spindles and rolls. One can readily understand this when it is realized that a good amount of current must be passed from the stationary part of a welder transformer to the rotating spindle and roll. Bearings, with or without rollers, can be used but these must be held to very close machine tolerances to allow no deviation in the flow of current. Here the alloy manufacturers have produced metals in combination to fulfil these requirements much better than in years past, although there is still considerable room for improvement.

Much of this development work is being done by the shops where production must go on with the minimum of unit costs. The finest of control apparatus is gone for nil if this one item is overlooked. In this endeavor, the Nash-Kelvinator Corp. has spent considerable in research to produce the best in order to keep production on the move with the minimum of machine down time and also the maximum uniform good welds. This company has been able to manufacture, for its own use, spindles that will produce many times the quantity that were produced prior to this experiment.

The choice of timing unit here will govern the class of work and what the welding transformer will produce efficiently. The writer has seen, with the use of different controls, transformers running so hot that it would destroy the insulation with one control and with the use of another control, the same transformer remain cool and produce more welds per day. Whether a control will allow the mechanical stress to become excessive on the welding transformer is governed by the way the current is turned on and off in its cycle of operation.

Since the introduction of mechanical operated contactors for interrupted seam welding, various novel ideas have been tried out. One form came with the use of tubes, not only for the control, but also using tubes for contactors. This tube control is a means of accurate control of both magnitude and duration of current flow delivered to welder. This control then allows any number of cycles "on" and "off" time and it then becomes a routine method to weld most any weldable alloy or combination, leaving only variables, as wear on rolls and flow of water.

Wheels are controlled to a great extent through the use of drivers that tend to hold the contact surface area uniform. When these drivers are unable to control this factor, wheels must be taken off and redressed.

Water here is an important factor and no set of hard and fast rules can govern all cases. Some steels, or alloys, demand a good flow of water over the work and rolls for quick cooling and others no water at all may be used. However, in either case, water must cool the rolls in order that they remain as cool as possible. On one grade of metal, water is applied to rolls and work ahead of the welding, but no water comes in contact with the welding heat, as this would destroy the characteristics of the steel. Too much stress cannot be made upon this subject, as the case may be, for even the best workings of a welder and timers can be destroyed by the improper use of water on the weld.

Pressure

No matter what the type of resistance weld is desired to be produced the question of pressure arises. Here again are several methods used, such as air, mechanical, combination air and spring, and hydraulic. With the use of air, in the average shop, we have the common fluctuations on the line that are taken care of now by storage tanks on the welders. Air is used to compress a spring and that in turn transmits pressure to the weld. Here again we get a small variation in the pressure on the weld. There are endless varieties of mechanical methods to compress springs to give this pressure that have some degree of accuracy. Where hydraulics are used, in most cases, an individual pump is installed with the welder and if the volume capacity is great enough, will produce a very high degree of constant pressure.

An example of what automatic welding has done in one industry can be related, and what is true here is also true in many cases. Rims, at one time, were butt welded, using two men to a welder, and work was clamped manually, also the flashing and push up was controlled likewise. A days work, at its peak, was some 1300 rims for nine hours for two men. The first fully automatic welder, using air operated clamping devise and a hydraulic push up, one man produced some 3100 rims for the same time. Since that time, improvements have been made in this form of welding so that this speed has been greatly exceeded.

Seam welders did very well to produce some three or four feet per minute of welding, and even at this rate, welds were doubtful. Today, on the same machines, with modern controls, the same grade of work is produced at the rate of eight to ten feet per minute.

Spot welders were made to operate at a peak of 75 to 90 spots per minute, but putting automatic controls on these welders the speed has increased to 200 or more spots per minute.

Controls

Looking around we find many types of controls on the market, with each manufacturer believing his product the acme of perfection. This may be true, but much depends on what service they are put to and, in many instances, what sort of care they have after being put to use. A good welder, or control, can be utterly useless in the wrong application or for the want of proper care.

In the application of automatic welding, a brief outline of some of the controls, which go so far to make the welder automatic, should find a place here.

There are several forms that fit the spot welder. Some are fully electrical in operation, some air operated, some combination electrical and air, some mechanical and others tube control with and without contactors. Many spot welders today have been designed for the use of air for pressure so that a number of controls have been designed to meet these needs. One control uses a push up button on welder, which in turn operates a solenoid valve that controls the air to pressure cylinder. When pressure is built up here, a pressure control valve is opened allowing air to a small cylinder on contactor, which closes switches by the movement of a cam on piston rod. The time element is governed by the rate of flow of air to this small cylinder on contactor. This switch can be made into a repeat type, that is, it will go through each cycle of operation in succession as long as operator holds the push button in. This form has been found to be as successful as any ordinary contactor allows it to be, but any such contactor will close and open at any point of the cycle. For the average welds, this last part places no great handicap on the work.

Another form will use the same first operation, namely; the push button closing the solenoid valve, which in turn allows air to flow to pressure cylinder. A pressure switch is in the line and when the air has reached this pre-set pressure, this switch closes and makes contact for the solenoid on contactor and control unit. A current transformer in the welding line passes current to a condenser, which regulates the timing. The rate of flow to this condenser is controlled by a variable rheostat, and when condenser is loaded the excess causes the switches to open and timing is complete.

Here again we have the question of contactor in the load line, and where it is not objectionable the timing unit performs its duty cycle. This type of unit has tubes at work, but only for the proper functioning of timing unit.

Many such forms are made, but in one instance they are alike, namely, a contactor must be used to open and close the load to the welder. Another type of control has entered into the field, which is fast changing the older conceptions of how a weld should be made. This type uses tubes to make and break the welder load. In this case the load is on and off almost instantaneous, so that there are no mechanical movements to rely upon for accuracy of timing. Using this form, heavy loads, for a very short duration, may be made. This will confine the welding heat to its proper location and not saturate the stock to be welded. In many cases, good consistant welds may be made with a small, or without any, amount of indentation and no discoloration to the stock welded. In some cases of alloys being welded this feature is absolutely necessary for the proper welds. It is a far jump from the first cam operated contactors to this form of timing and control.

Gun Welding

Another form of welding that is fast becoming popular is gun welding. At first this method of resistance welding was put to use through sheer necessity, but today it has found a field all of its own. In this form, two points are made to press together, either by an air or hydraulic cylinder, and gun is held in the hands. Heavy copper leads, up to 10 or 12 feet in length, are attached to form the power circuit from the transformer situated away from the work. The necessary water hose, hydraulic hose, or both, and timing control cables are also attached.

With this small hand tool it is possible to weld in otherwise inaccessible places. The gun is used, in many cases, to do the spotting after the work has become properly assembled in jigs. Here again is the problem of an automatic weld. Many guns today have an air valve on the gun handle, controlling air movement to the pressure cylinder. After a pre-set pressure is reached control is set in motion, but if operator does not continue to hold valve on gun timing unit will complete its cycle while air pressure in main cylinder is decreasing or when points are opening. Here the fully automatic has been developed so now the operator pushes a button and a complete timing cycle is made, irrespective of how long the operator holds the push button. This one feature alone has been the means of producing thousands of uniform high strength welds where the former method produced consistantly good and bad welds. Here again the proper sequence of a weld made automatically has paid good dividends. In this, as well as any spot weld, the automatic weld must follow through the series, namely, pressure applied and held, without diminishing, until after the timing unit has completed its cycle. Movements on any switch solenoid valve, or any apparatus, in the line of the welding cycle will determine what speed may be attained at the points.

Many fixtures, endless belts and index plates have been designed to get work in welding position and out again with dispatch. These items, with automatic timing, have done so much to assemble parts in a neat, orderly fashion. With the use of all these fixtures and good timing apparatus it is the logical thing to proceed, first of all, to make several sample welds by the trial and error method. This will give the inherent characteristics of the total set-up and also determine the best welding points in each phase of the set-up.

Automatic welding is by no means the final answer to all the ills of welding any more than one patent medicine is a cure-all for all ills. Each individual application must be analyzed and the proper procedure followed for any particular problem. The best solution for any proposition can be helped along, first, by the selection of a man, or men, well versed in welding and disinterested in any one particular brand of equipment. Second, the well designed and made machine. Third, accurate timing of the complete welding cycle. Fourth, the proper selection of die materials, and last, a thorough study of the characteristics of the product to be welded.

Tests and Arc Welding in Ship Structure*

By W. P. ROOP†

THE first question every visitor to a ship under construction asks is this—how much further have we to go before realizing the all-welded ship?

The answer is that we have already passed that point; for the perfection of design lies in adapting materials and processes to specific requirements. An Eskimo kayak is a more perfect implement than a dugout made of one piece of wood because of its composite construction. In the same way the hulls of Naval vessels are made of a variety of materials joined in a variety of ways.

In this paper we have selected for detailed consideration a single process of making joints, namely welding by the electric arc. But in one respect, at least, this process is typical of all the others, indeed, of industrial process generally; it is dependent for successful application on testing.

Somehow the Eskimos have freed themselves from the limitations of cumbersome monoxylic construction without the use of laboratories. In point of historic fact, the shipbuilding industry generally has had little use for laboratories.

But the process of arc-welding steel is a gift to the shipbuilder, if not exclusively at least essentially, of the urge for experiment. The institutional embodiment of experiment is the laboratory, and the function of the laboratory is to make tests.

While it is impossible actually to separate the different phases of testing as applied to welded construction, it helps to consider them separately.

I. Tests of Material

(a) *Electrodes*

Practice tends toward the most direct type of test. Will a given wire make a good weld? Give it to a good man, with good working conditions; it only remains to decide whether the weld he makes is a good one. Such points as rate of deposit, sensitivity to humidity, or to unfavorable disposition of parts to be joined, tendency to undercutting, latitude with respect to electrical operating conditions are simply observed by trial.

Contrasted with these direct trials are indirect methods, such as physical and chemical tests on the wire, which are less used now than formerly.

(b) *Welding Machinery and Equipment*

This also is material which must be tested. Well standardized tests of efficiency, power characteristics and control gear of generator sets and the like assure that legitimate demands can be met. The question as to what demands are legitimate is entirely separate. For example, spectro-photometric tests of goggles are useless unless it is definitely known what wave lengths and intensities are injurious. Such a question is one for medical research. And the qualities desired in generator sets are for the welders to specify, not the weld testers. When we know what is expected of welding equipment it is easy to know by direct tests whether we can get it or not.

(c) *Base Metal*

A similar directness in dealing with different base metals has not yet been achieved. Aside altogether from the question of what constitutes a good weld, there is the point that base metals have other requirements to meet, and are subject to limitations inherent in manufacturing processes.

It seems impracticable to ask simply: Can good welds be made with this base metal? but somehow it becomes necessary rather to ask: What properties in the base metal favor good welds?

As a person who has tests to make, I am sorry that this is so because it complicates test procedure so greatly, not only the technique of making the tests, but that of interpreting them. However, it is a difficulty that cannot be avoided.

To simplify it as much as possible we will agree that acceptable material in the base metal is that which will not prevent good welds when the other conditions are such as prevail in practice.

For example, it is known that too much carbon spoils welds. In order to use carbon content as a criterion of acceptability of carbon steel for welding we must know how much is too much, and that depends on how the weld is made. With usual methods of welding ship structure such a limit can be determined, and is commonly considered to be about 25 points in plain carbon steel. But if the sample for analysis comes from a part of the ingot at a distance from the point where the weld is to be made, there is a complication. Such complications are increased when low-alloy steels are to be judged as to their weldability by their chemical composition.

Is it possible to say that weldability is not affected by heat treatment of the base metal? One might suppose so since the heat of the weld raises the base metal locally far above critical temperatures. Such an easy answer is illusory, however, since there is always a zone in which the final result depends on the initial grain structure of the base metal.

So also with the thickness of the base metal, and perhaps its condition of cold working or other features of manufacture. It is necessary that all such features be considered with respect to their effect on weldability.

When we have all this information about a base metal, is that enough for judging the value of the metal for welding? We presume that it is, for that is how we specify requirements for weldability.

But how much simpler it would be if we could only take a piece of the base metal and find out whether it is weldable by trying to weld it. I am not speaking for the steel makers who must know how to make steel that is weldable, nor for the welders who must be able to make good welds, but only for the designer who must say: this steel is weldable, that one is not.

A favorite criterion of weldability of a base is low susceptibility to air hardening. This is just as indirect as chemical composition, but it is considered to be such a good indicator that some investigators are satisfied to judge weldability of a steel by hardness measurements only, without correlated physical tests.

In the early days of welding it was soon found possible

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* This paper represents only personal opinions of the author and in no way the official attitude of the Navy Department.

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† Lieutenant Commander, (C. C.) U. S. Navy.

to make welds that were strong enough to cause failure in the base metal rather than in the weld itself. This was at first regarded as evidence that joints of 100% efficiency had been produced, but presently the fact emerged that the weld had weakened the adjoining base metal. We now believe that this is due to the severe heat treatment resulting from the presence of molten metal on a base which started out at air temperature. Temperature gradients both on time and position are enormous and in the completed weld there is a complex knot of residual stresses and deformations further confused by abrupt variations in the properties of the metal itself both in the base and in the deposit.

This knot, the hardness test presumes in some degree to unravel. When applied to homogeneous pieces of metal, hardness gives moderately close correlation with ultimate tensile strength. As applied to welds after sectioning it gives beautiful charts of hardness topography which reveal a ridge of high values following the limits of the affected zone as shown by etching. This ridge runs up to a peak (in the case of a fillet) as it approaches the toe of the fillet, though the maximum occurs a little within and not at the surface of the metal.

The first embarrassment encountered in applying the hardness test arises from the flood of numerical data which it produces. This is overcome by dealing only with the peak value, and all the other spots are rejected after they have served to indicate where and how high the peak is. Next: Shall we use the gross peak value, the net increase over the hardness of the base, the ratio of gross to net or some other inferred quantity, in our attempt to correlate hardness with weld quality? All these procedures have been used, all are more or less unsatisfactory. Although there is a trend of high hardness which runs parallel to low ductility in the completed joint, attempts to be more definite than that have been disappointing; it cannot be said that hardness is more than a rough index to low ductility.

Hardness itself is only an incidental feature of welded joints. The use of the hardness test for exploration of inhomogeneity on a very fine scale is its greatest claim to respect. There is no reason to suppose that a hard spot is a point of weakness, except through the following chain of inference: "High hardness = high ultimate tensile strength = low ductility = early rupture beyond the yield point." But this chain of inference has weak links. It completely ignores the facts that the point of highest hardness is not at the surface, and that a crack such as that which is assumed to start at the point of highest hardness, while undesirable, may have no great significance in a material of high notch toughness.

And in particular it takes no account of the differences between materials with respect to the relation between hardness and ductility. A degree of hardness which represents unacceptable brittleness in one material may imply only insignificant brittleness in another. It should never be forgotten that the ultimate object is not just to keep hardness down, not even just to find a weldable base, but to produce *satisfactory welded structures*.

II. Tests of Welders

It has become a truism that weld value depends on personal qualities in the welder; a personal qualification test is easily devised, but demonstrates only that a man *can* make a satisfactory weld. As a check on what he *does* do, quick test-welds of small pieces made in a brief interruption of production work have been proposed, but so far as I know are not widely used. Periodical requalification has sometimes been required, but such tests are more commonly made only on demand. Wherever possible the drift of practice is away from dependence on personal integrity and skill of the individual welder and toward fuller control of process and technique.

III. Tests of Welding Techniques

Many details of operation are within the control of the welder, but can be specified more definitely than personal skill and integrity. Thus such details as electric voltage and current, length of arc, weaving, preheating, sequence of multiple beads, wandering and peening; all are comprised in technique.

What, under given circumstances, is the best technique? No subject in welding is subject to more difference of opinion, which demonstrates that tests of the validity of technique have not been conclusive. Here is a case in which the direct test doesn't work well, partly for the reason that equally good welds can be produced by different techniques, and partly because no convenient method exists for defining techniques actually used. For example current value continually fluctuates, and if an autographic record of these fluctuations is taken, there are difficulties of interpretation. There are broad distinctions such as that between wandering, successive continuous beading and cascading, by which heat is graduated from wide distribution to narrow concentration. But as between such broad differences there is a strong tendency to accept the first tried which doesn't crack on cooling, and use it wherever it is to that same degree successful.

Associated with the technique of making joints is procedure or sequence in assembly of extended structures. This also is a matter in which differences of opinion and of practice persist, and from this fact we again conclude that no decisive test by which to be sure of the best sequence is available.

Perhaps the testing of techniques and sequences had best be left just where it now rests; any technique is satisfactory which makes good joints.

IV. Tests of Joints

The various threads of welding activity come together for the first time in the joint. If the joint is part of the completed structure the test must be nondestructive, and consists mostly in a search for cracks. This search has been very diligently prosecuted, so that I feel some doubts whether full advantage has yet been taken of the freedom from internal defects which present-day practice in testing affords. Specimen joints with given materials and techniques identical with those used in the job, when tested to failure, are considered to give indications of what is occurring in production. Such specimens may be specially devised for disclosing defects, as in the various kinds of bend test, and are then more drastic than service tests. Or, as in the tensile test, they may give data, such as ultimate strength and yield point, which are directly comparable with service stresses and so may be used by the designer. However, such values must still be diluted with safety factors, partly because specimen joints are never exactly like production joints.

Ductility in its various phases is the subject of a great variety of tests. Although ductility is of predominant importance in a joint or a base metal it has never been given a dimensional definition, with the result that its numerical values have meaning only by reference to the specific types of tests by which they are obtained. It is not even assured that the scale of the specimen does not affect the result; for example, a sub-size tensile specimen may give a value of reduction-in-area different from that obtained in identical material from a specimen of standard size.

The great variety of types of joint need not be con-

sidered except for observing that jigs for loading must be adapted to suit. A further dilution of test values for design use is necessary in consideration of the departure of test loads from service loads.

From another angle, loads on welded joints may be varied with respect to time, which brings us to endurance tests and impact tests. These arise in a desire to bring loading closer to the conditions of service, although this advantage is lost when, for the sake of uniformity of results and isolation of variables, specimens of very precise contour are machined from the joint. This procedure reaches its climax when a distinction is drawn between the weld and the joint, and the specimens are cut in such a way that all base metal is removed and only deposited metal remains.

Let us regard this maze of test procedures with a critical eye. What we want is a joint that will behave in service as if there were no joint, but only uninterrupted base metal. The perfect joint is one that agrees with the metal in

1. capacity for resisting stress without excessive or permanent deformation,
2. capacity for plastic readjustment under local overstress,
3. capacity for energy absorption under general overstress and
4. capacity for endurance under repeated stress.

The deficiencies of the joint may arise in its departure from the intact metal either externally, as in the contour of the joint (straps, fillets, reinforcements) and in surface conditions (notching, corrosion), or internally, as in the general inhomogeneity in crystalline structure, and even presence of voids.

But when we have applied the specific tests mentioned, all of them, and obtained their evidence as to the sources of insufficiency in the joint under all the different conditions of test loading, with what assurance can it be predicted that the joint will give satisfaction in service.

Assurance on this point is very vague indeed. Supposing that we feel a safety factor of 5 to be necessary, we may say, as Mr. E. L. Robinson recently expressed it, that we are assured as to 20% of what is going on, and are only guessing at the other 80%.

What is necessary in order that this assurance may be increased? Two things mainly: First, the conditions of service must be more accurately known, and second, the conditions of test must more closely approximate the conditions of service.

V. Tests of Designs

Before any structure can be prepared for a required use it is necessary to know what loads that use will imply as well as what structure is needed for resisting a given load. The designer cannot avoid either of the two parts of this double responsibility, which are essential.

The responsibility is accepted, the design is prepared, and it involves many joints of many different kinds and sizes, in which frequent compromises are made between the requirements of technique in making joints, sequence in assembly, convenience of access and handling, the exigencies of workmanship during construction and of performance after completion.

With such a design before us, what estimate in advance of construction, can be formed of its adequacy?

Data on loads are obtained by field measurements of response in existing structures or perhaps of load directly. When the loads are known they may be applied on reduced scale to a model of the structure. Or the model may be such that dependence can be placed upon similitude in the load as well as in the structure.

This is not the place for a discussion of models; but when scale effects are properly eliminated model tests afford checks on design obtainable in no other way. Unfortunately the joints are the source of great difficulties in obtaining similitude, so that models have received little use in the study of welded designs, and the benefits, such as test to failure, low cost and ease of control, have not been widely realized. If the scale is not too small, say $1/4$ to $1/2$, there is still a wide margin in cost between model and full scale, and at the same time, if the full scale scantlings are heavy enough, sufficiently homologous joints can be obtained.

Small size structures built of plating heavy enough for satisfactory welding may be regarded as being in full scale; it is not necessary to indulge in recondite generalities about similitude when one uses a smaller structure as a guide in designing a larger one, provided materials, joints and loads are similar enough so that the major difference is in size.

VI. Tests of Completed Structure

But the need still exists for tests after completion.

Where production even in moderate quantities prevails, selective tests to failure are feasible. Complete assurance of freedom from defects is sometimes sought through proof tests which demonstrate a definite margin of strength in every unit. Life tests may measure the time required for such agencies as corrosion to reduce this margin to zero.

But the ultimate test is that of service. If any product gives satisfaction in service there is nothing more to say about tests, whose only function is to accurately predict whether the service will be satisfactory before it is too late to do anything about it.

The operative test of the completed assembly is called a trial. Since structures are needed for service immediately when they are completed there is always great urgency about trials, and since further a failure on trial is costly, it is most necessary that the assurance of success on trial should be as complete as possible.

The trial is the time for ascertaining the conditions of service. Assuming that this is accomplished, the whole problem of anticipating the performance of a full scale structure by application of tests prior to completion reduces to the need for making the conditions of test commensurable with the conditions of service.

This is the major thesis which I wish to advance in this paper, that the final object of all the varied tests that have been mentioned is to assure satisfactory service in the completed structure, and that in so far as the conditions of test depart from the conditions of service their equivalence must somehow be demonstrated.

The conditions of primary loading of ship structure are as follows:

(*a*) Loads are cyclic, with frequent full reversal from tension to compression.

(*b*) Maximum values fluctuate strongly, but the number of cycles in which stresses may reach critical intensity will never be millions, hardly hundreds of thousands, ordinarily only tens of thousands.

(*c*) Following each period of overstress a long period can be expected in which stress does not exceed very moderate limits.

(*d*) Standards of metallic surface conditions are much worse than in operating machinery, due to impossibility of eliminating roughness and to presence of salt water.

In view of these service conditions it is necessary that tests be made under corresponding conditions; until this is done we must still be content to measure only a small part of which is going on and guess at the rest.

Tests under working conditions can never be precise because working conditions fluctuate. Along with such tests we must make many indirect tests of conventional type under artificially standardized conditions for the purpose of explaining the results. In case of service casualties, such indirect tests are our only resource. What we must now do is to provide ourselves with harmless casualties; in learning how to explain them we shall then also learn how to avoid them.

Mechanical Cutting in Railroad Work*

By H. BASS†

EVERY Railroad Officer should be vitally interested in any process which will save the railroad money and at the same time, turn out a better product. With a background of many years of sound theory and practice, this process is employed to produce simple as well as the most intricate and difficult shapes with ease, speed and precision. It antiquates production methods which have long been in use. It revolutionizes shop practice and reduces costs. The method I refer to is mechanical gas cutting.

Railroad Production Problems.—The Railroads have a major problem of maintenance and repair work which was formerly carried on at a number of points, but present day operating methods have changed, and this work is now carried on at a centralized location. The repair parts are made to standard dimensions and made on a production schedule. Highly mechanized machines are essential to lower production costs, and mechanical gas cutting fits into this picture because of the large range of locomotive and car work to which it is peculiarly adapted.

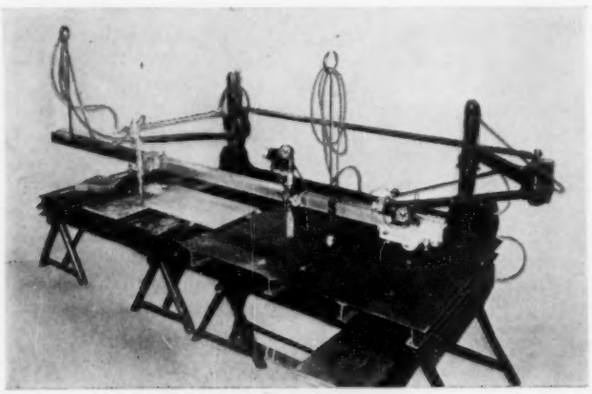


Fig. 1—Machine for Gas Cutting

Machine Gas Cutting.—By machine gas cutting, I mean the application of the gas cutting process to the production of shapes from rolled steel slabs, plates and rough forgings, with oxyacetylene cutting torches supported and guided by machines and therefore, distinct from hand torch cutting. The flexibility of the process when accomplished by suitable machines is equal to that of the hand process. Its benefits apply to the Blacksmith Shop, the Boiler Shop and the Machine Shop.

Many changes have been made in the metal working practices of those railroad shops which have taken full advantage of the use of mechanical gas cutting, and the demand for this equipment is increasing in those *locations* where it is installed.

The questions naturally arise, what metals can be cut, what effect has cutting on the metal, what are the limitations as to thickness, what degree of accuracy can be obtained, are specially trained operators required, can cost be determined, how do they compare with present practice and what will be the quality of the work?

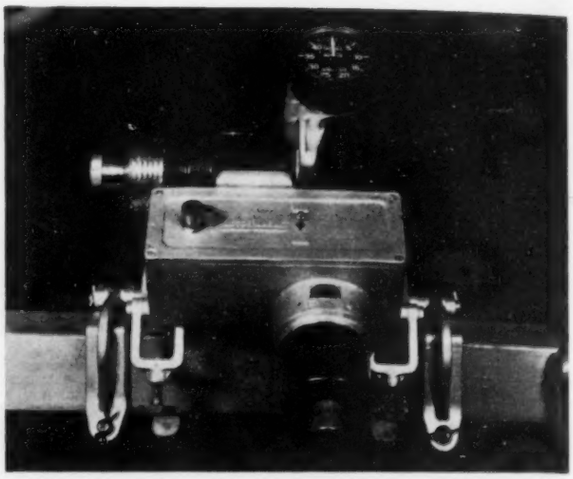


Fig. 2—Magnetic Tracing Device Equipped with Motor, Tachometer, Quick Speed Change Device and Hinged Clamp

What Metals Can Be Machine Cut?—Practically all classes of iron and steel used in railroad work can be machine gas cut. Steels under 0.30 per cent carbon can be cut cold, or without heat treatment before or after cutting. Machine gas cutting of these steels is just as well standardized as shaping by any of the accepted machining methods.

Steels in the higher alloy group can also be cut without difficulty. These steels should, however, be preheated before and annealed after cutting. When this practice is followed they are just as easy to cut as the lower carbon steels and no difficulties in use due to gas cutting need be anticipated.

Effect of Cutting on the Steel.—The effect of flame cutting on the steel is a logical question. Flame cutting has no appreciable effect on the physical and chemical characteristics of the metal in the low-carbon steel group, which constitutes the major portion of the steels used on rail-

Fig. 3—Swing Link Hanger Steel Blank

* To be presented at Annual Meeting, AMERICAN WELDING SOCIETY, Atlantic City, October 18–22.

† Welding Supervisor, New York Central Railroad.

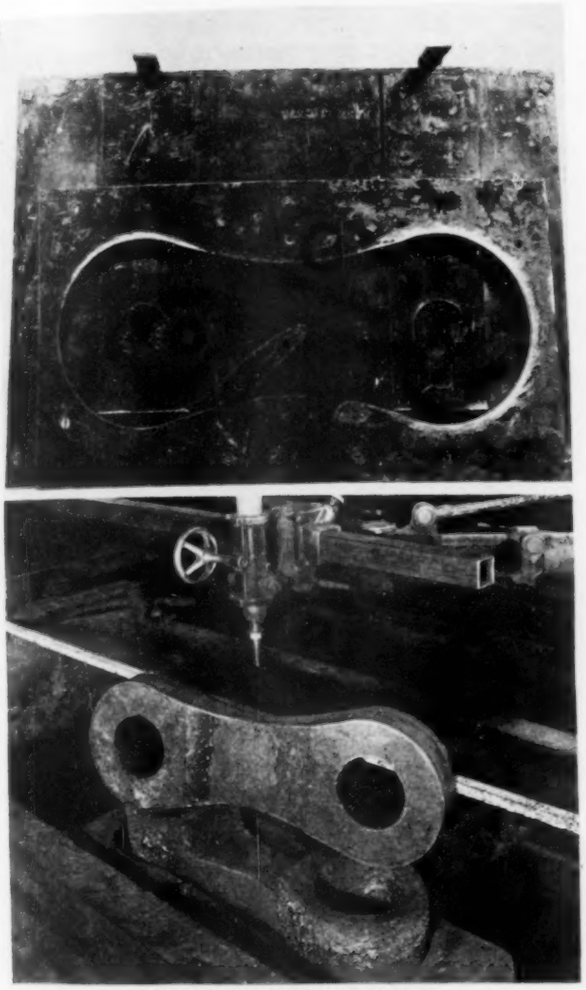


Fig. 4 (Top)—Swing Link Hanger Jig
Fig. 5 (Lower)—Swing Link Hanger After Cutting

roads. This is why these steels are cut cold and need no heat treatment, except in the case of large forgings which should be annealed and cut hot, because of the strains set up by forging.

Annealing steels over 0.30 carbon tend to have some migration of the carbon to the flame cut surface. When correct practice is followed and these steels are preheated before cutting and annealed afterward, they are just as easy to cut as lower carbon steels, and can be machined without difficulty afterward. The annealing returns the steel to practically its original state. Extensive researches both in this country and abroad have established this fact beyond a doubt.

Where machining or grinding operations are performed after cutting, the comparatively small area affected is completely removed, and there need be no concern about the effect of flame cutting on the metal.

All plate and forging thicknesses common on railroads offer no difficulties whatever, to the machine gas cutting process. The oxyacetylene torch smoothly and evenly severs steel far beyond the practical range of cutting by mechanical means.

Flame cutting can be relied upon for reasonable accuracy and the squareness and clean finish of such cuts together with the sharp top and bottom edges, compare favorably with rough machining.

Many shapes can be cut to layout lines, and the degree of accuracy depends on the thickness of the material and the intricacy of the shape. Where no machine finish is desired, ordinary steel plate can be cut to the finish line. On higher carbon steels, and parts which are to be machine finished, only a sufficient tolerance is left to allow for easy and economical machining. Since tolerance varies with the grade of work to be done, it may readily be compensated for by making due allowance on the drawing or cam used.

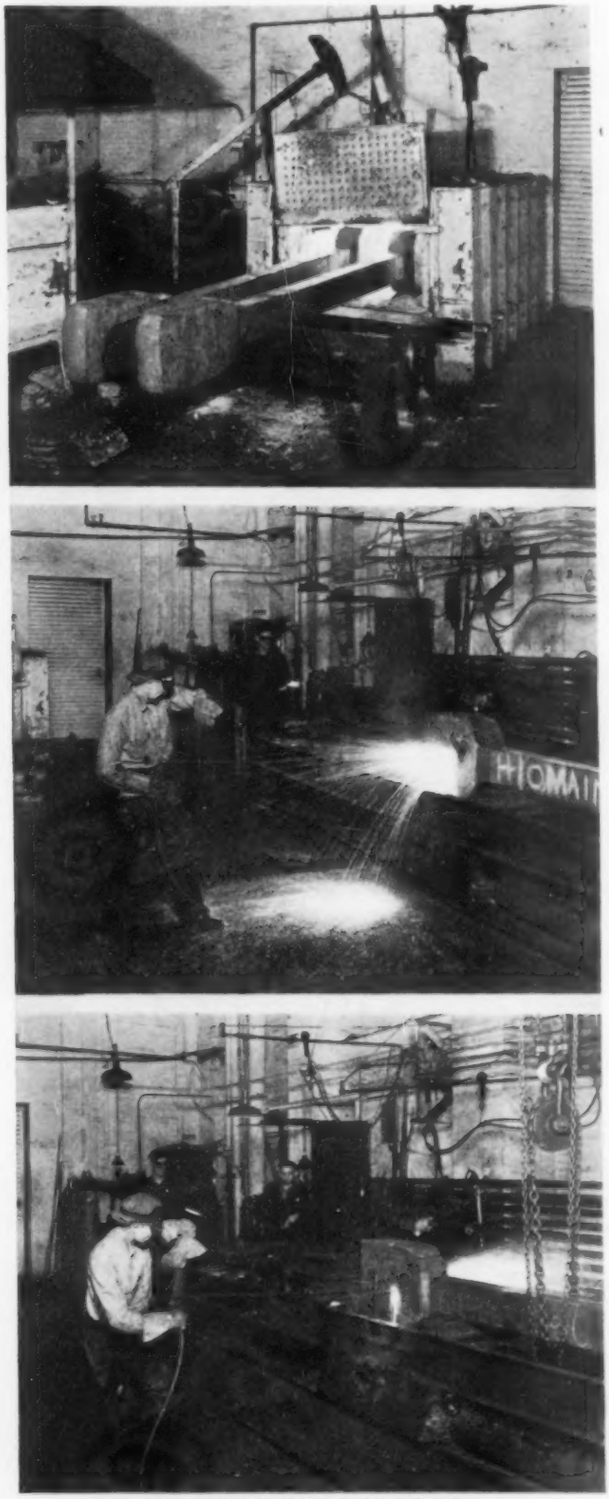


Fig. 6 (Top)—Big End of Main Rod in Preheat Furnace
Fig. 7(Center)—Piercing Starting Hole with Oxygen Lance in Big End of Main Rod
Fig. 8(Bottom)—Hole Burned Through 8¾ Inches Thick

Fig. 9 (Top)—Cam Used for Cutting Large End in Starting Position
Fig. 10 (Lower)—Cam Used for Large End After Cut Has Been Started, Gate Closed

The question of getting good operators presents no difficulties. Any shopman of average intelligence and ability can learn to operate a flame cutting machine. Almost any trained metal worker can quickly pick it up.

Gas cutting speed and consumption costs are items that vary depending on the kind of steel, thickness, intricacy of contour and the quality of finish desired.

This process has progressed far beyond the laboratory stage and has proved its advantages over a period of time. The capabilities of mechanical gas cutting machines and how they function to produce the desired shapes are better explained by descriptive figures.

Figure 1 shows machine used for gas cutting. It is a simple type of pantograph assembly with the cutting torch clamped to a connecting bar on the left. This is moveable to any position. At the right is the magnetic cam tracing device, also moveable on the bar. It consists of a variable speed motor, driving a magnetic roller about one inch in diameter. The template is made about $^1/_8$ inch thick and clamped to the table. The roller is held to the cam by an electro magnet which is driven by an electric motor and follows the design of the cam.

Figure 2 is a close-up of the magnetic tracer itself showing motor, magnetic driving wheel and clamps for holding on the bar with switches for motor and magnet.

Figure 3 shows cut of swing link hanger cut from solid blocks of steel. Note the two drilled holes in the piece. These are the centers used for lining up the jig to place it in correct cutting position on the machine.

Figure 4 is the jig in the center of which are the two centers to hold the magnet wheel. These centers are spaced $^3/_{16}$ inch longer from center to center than the holes in the piece, the reason being that since the piece is drilled cold, and preheated before cutting, it will lengthen that amount. The jig is clamped on the table and magnetic wheel placed in the center, the small handle at the top opening a gate to let the magnet in and then closed. The preheated piece is positioned for cutting by placing on the table and moving the torch on the bar till it comes over the drilled hole. The magnetic tracer is now moved into the other gate for the opposite center and locked, and the link blank moved, so that the center of the torch is directly over the drilled hole. The jig is now clamped to the table.

We are now ready to cut out the two center holes. The torch preheat is lighted and when the steel is hot enough, the oxygen valve is opened and the magnet motor started, the gate opened and the magnet roller starts from the center around the outside of the template. When once well started, the gate is closed again so that it will finish and make a truly circular hole.

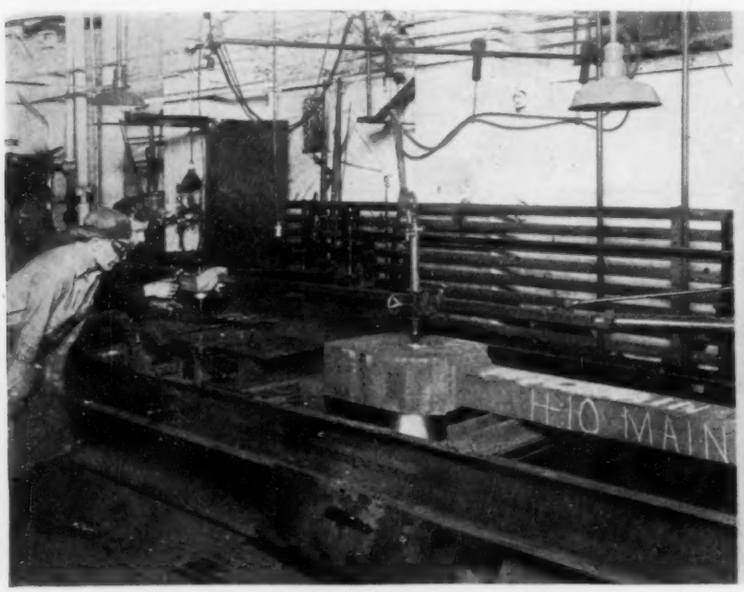


Fig. 11—Starting Cut in a Lanced Hole on Big End of Main Rod

Fig. 12—Center Cut Nearly Finished of Main Rod

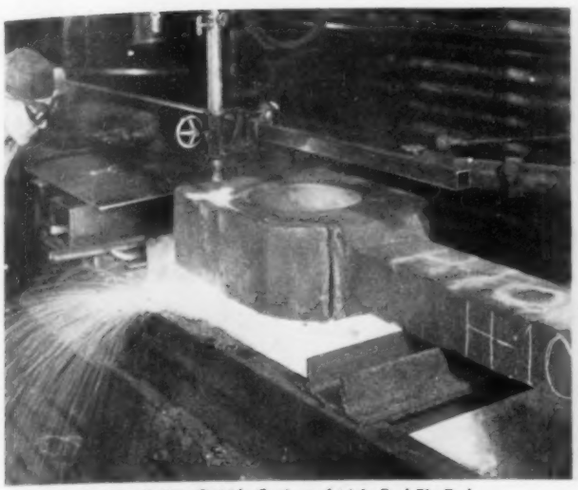


Fig. 13—Cutting Outside-Contour of Main Rod Big End

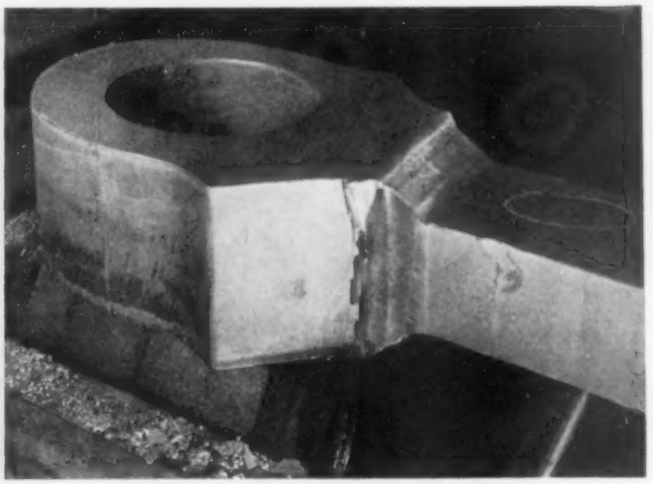


Fig. 14—Close-Up View of Finished Cut on Main Rod

The same procedure is used for cutting the opposite hole. We are now ready to cut the outside. A start is made on the edge of the piece near the main gate. After the cut is well started, the gate is closed so that the magnet wheel will ride over it and run into the cut previously made, when the torch is shut off and the motor stopped, and the cut finished. So accurately has our work been done that all that is necessary to finish the piece is to have the two holes reamed.

Figure 5 shows finished piece, setting on top of the support used when cutting. The cut centers drop down the holes, and you can just see the outside edge just cut away at the base of the support.

Figure 6 shows the big end of the main rods in the preheat furnace, ready to come out. After they are preheated to 1200 degrees, they are ready to be cut, this being the temperature at which no warping of the steel takes place, and which also eliminates all checks or cracks.

Figure 7 shows piercing a starting hole with the oxygen lance. The operator in the background has heated a small spot just off the center of the big end and the other operator using 110 lb. pressure of oxygen is burning the hole through.

Figure 8 shows the hole burned through which was accomplished in about 30 seconds.

Figure 9 is the cam used for the large end. In the center of bar across the hole is a notch which fits the magnetic tracer, and at the bottom of the piece is another similar notch. These are used for lining up the rod and jig. The rod has come from the blacksmith with 2 center punch marks. The rod is made ready for cutting and positioning by centering the cutting torch over the center punch mark on rod center while the magnetic wheel is placed in the center notch of the jig, it being necessary to move the jig about until this is accomplished. The tracer is now placed in the other notch and the torch tip should center over the other center punch mark on the rod. The jig and the rod are now properly located and are ready for cutting, therefore, the jig is clamped fast to the table. All this can be done in much less time than it can be described.

Fig. 15—Jig Used for Cutting Small End of Main Rod

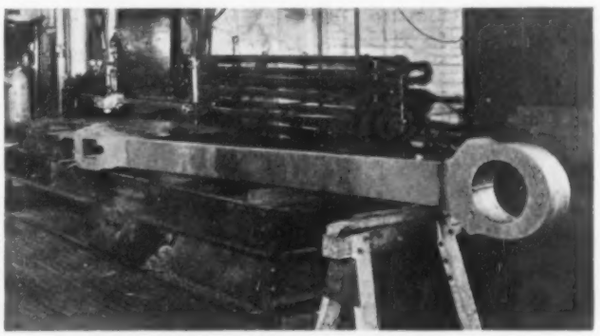


Fig. 16—Main Rod After Cutting

The cut is started in the pierced hole and this was made just off the center along the starting gate, and as the cut proceeds along and starts to cut the center curve, this gate is removed and the entrance gate to form the edge rod closed as in Fig. 10.

Figure 11 shows the start of the center cut and Fig. 12 shows cut nearly finished.

Figure 13 shows cutting the outside contour. Neither jig, rod nor torch has been moved.

Figure 14 is a closeup view of the cut showing its smooth even surface. The small end of the rod is cut in the same way and Fig. 15 shows the jig used, which is used in the same way as just described for the large end.

Figure 16 is the rod after cutting is finished, with the cylinder manifold and machine in the background. No cutting is done on the main part of the rod as this was prepared by the blacksmith to blueprint dimension $^1/_4$ inch more than finished size. In making jigs and templates for rods, they are made the size of the finished piece. The magnet roller is 1 inch in diameter so the finish is $^3/_8$ inch in diameter larger than the template on outside cutting and smaller on inside cutting. This is ample allowance for finish machining, and leaves the same amount of stock to be removed by machine tools which is easier on them.

Welding in Tanker Construction*

By T. M. JACKSON†

FOR several years welding engineers have been engaged in research work which has advanced welding in ship-building to the point where it is now recognized by both ship-builders and ship owners, not with suspicion but a natural development, as a means of saving weight, and of securing greater simplification and economy in ship construction. By the elimination of indirect connections, rivet heads, etc., the welded structure provides smooth surfaces which permit good drainage and easy cleaning and are subject to less surface corrosion. The advantages and possibilities are practically limitless and at present it is hardly possible to say how far they will lead in modifying present structural design. There is a natural tendency to modify it only to the extent that present welding technique and knowledge permit.

The first self propelled vessel to be electrically welded was the "Fullagar," which was built in England in 1920 and which, to the author's belief, is still afloat and doing excellent work. While this vessel proved that welding could take the place of riveting, no saving in weight was accomplished as the vessel was originally designed as a riveted structure. One of the first all-welded self-propelled tankers built in this country was the "White Flash," a vessel 201 ft. x 2 in. long overall, 34 feet beam and 12 feet molded depth built by the Sun Shipbuilding & Dry Dock Company for the Atlantic Refining Company in 1930. This was followed three years later by a duplicate ship, the "Franklin," for the same owners. Both vessels have surpassed expectations and proved that welding could, with confidence, be substituted for riveting. A bold initiative, both by the owners and builders, was taken in February 1936, when the Atlantic Refining Company placed with Sun Shipbuilding & Dry Dock Company an order for a tanker 542 ft. 5 in., long O.A., 70 ft. beam and 40 ft. depth of 18,500 D.W.T. in which the entire cargo tank space extending from the engine room bulkhead to the forward end of tank space, a length of 353 feet was to be 100% welded construction. In March 1937, the same owners placed a repeat order followed by an additional contract for a similar vessel for the Sun Oil Company, making at the present time

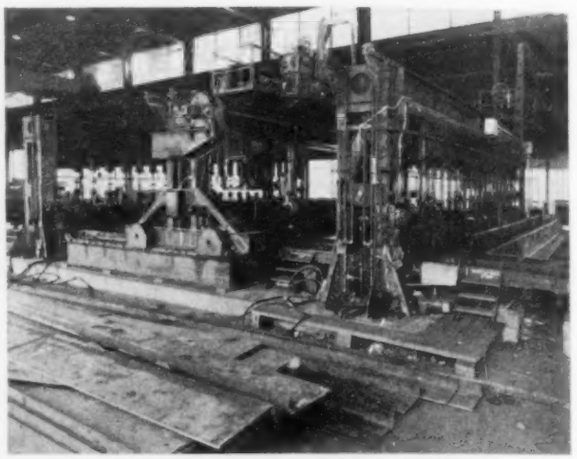


Fig. 2—Automatic Welding Machines in Sun Shop. Butt-Welding Machine Shown Clearly at Right

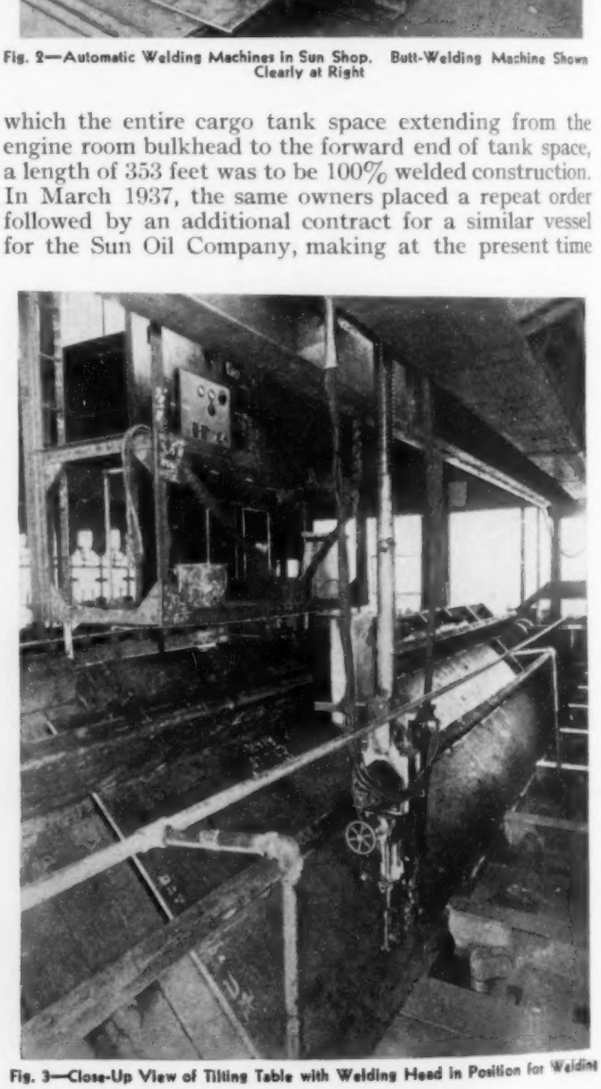


Fig. 3—Close-Up View of Tilting Table with Welding Head in Position for Welding

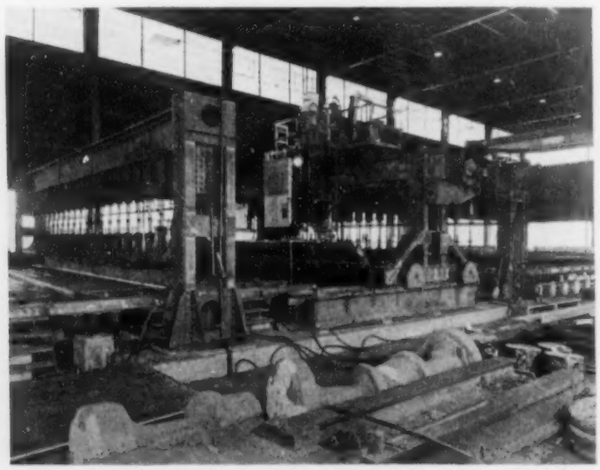


Fig. 1—Automatic Welding Machine Layout: (Left) Tacking Table, (Center) Tilting Table, (Right) Butt-Welding Machine

* To be presented at Annual Meeting, AMERICAN WELDING SOCIETY, Atlantic City, October 18–22, 1937.

† Ch. Electrical and Welding Engineer, Sun Shipbuilding & Dry Dock Company.

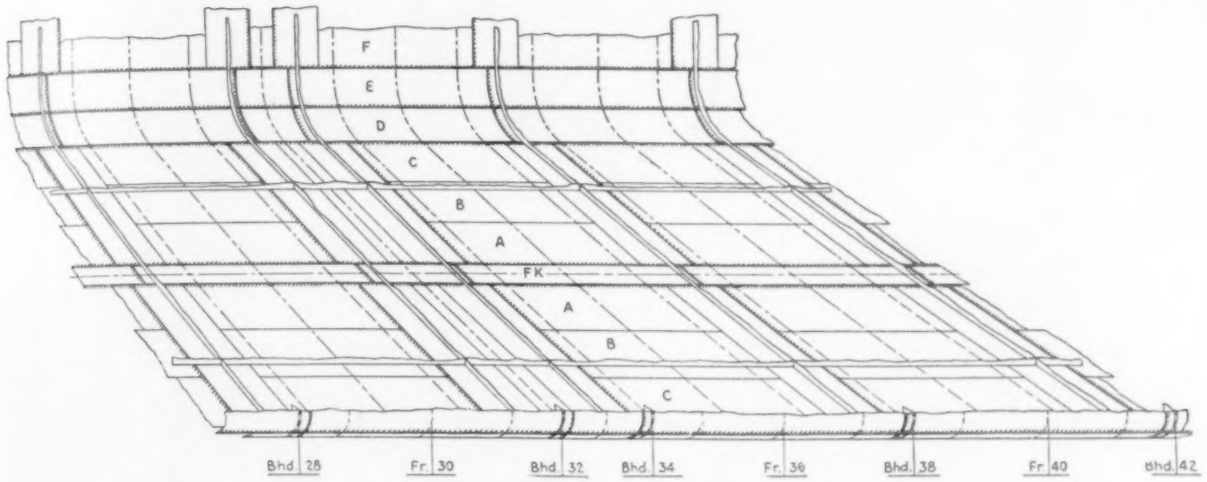


Fig. 4—Bottom Shell Plating. Shaded Lines Indicate Field Welds

three tankers, each over 18,000 D.W.T., with tank spaces completely welded. In addition, the same builders now have under construction six other tankers of 12,900 D.W.T. which will have all interior construction of cargo spaces, including longitudinal and transverse bulkheads, etc., welded. The shell of these six vessels will be riveted. The nine vessels mentioned will all have miscellaneous fittings; structures such as masts, rudders, foundations, storage tanks for oil and water, cargo piping, etc., of welded construction. Vessels having steam propulsion will have welded boiler drums, condenser shells, etc. Diesel engine driven vessels will have engine foundation, bedplate, main structure of engine and high pressure air storage tanks all welded. To date, rules of the Department of Commerce, Bureau of Marine Inspection and Navigation, will not permit the welding of high-pressure steam piping. A committee of the AMERICAN WELDING SOCIETY has been working for some time preparing a code and specification to cover such work. It is hoped this limitation will be removed in the near future.

The nine vessels mentioned represent orders from six companies, each operating a large fleet of tankers. I mention this work in our yard *only* because it presents concrete evidence of the confidence of a rapidly increasing number of owners, of a particular builder, of classification societies, insurance companies and government departments having jurisdiction in welding not only the hull structure but also the main propulsion and auxiliary equipment of large ocean-going tankers. It is now recognized that electric welding has become practically indispensable, that it is a sound method of construction to say nothing of the great saving in weight which in the first three vessels mentioned, will amount to about 15% for the hull structure alone.

Members of the AMERICAN WELDING SOCIETY will be most interested in the welding processes employed, methods of assembly and sequence of welding used in fabricating and erecting the hull structure of the three large vessels mentioned.

As a welded structure of this size had never before, to our knowledge, been attempted the greatest care and study was given to developing the best method of assembling and erecting the various members in the shop. Butt welding was adopted for all the main structure, lap welding being used only for bracket connections and joggled vertical panel plates at the longitudinal bulk-

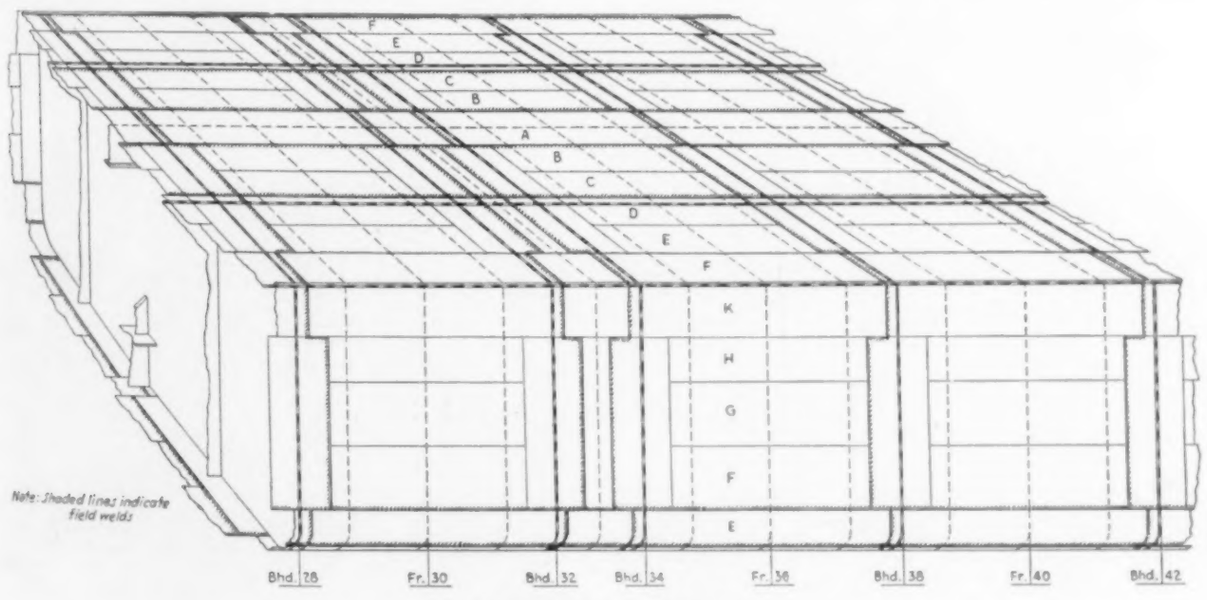


Fig. 5—Side Shell and Upper Deck Plating

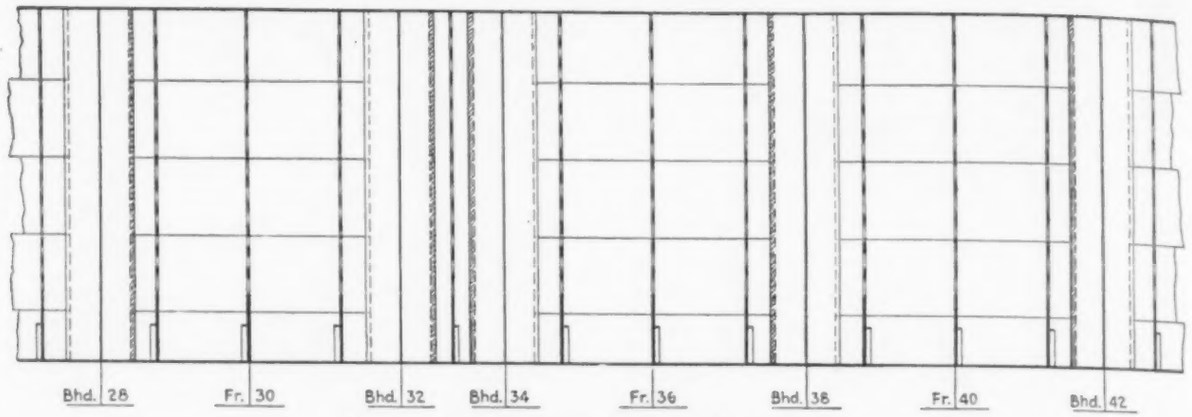


Fig. 6—Longitudinal Bulkhead. Shaded Lines Indicate Field Welds

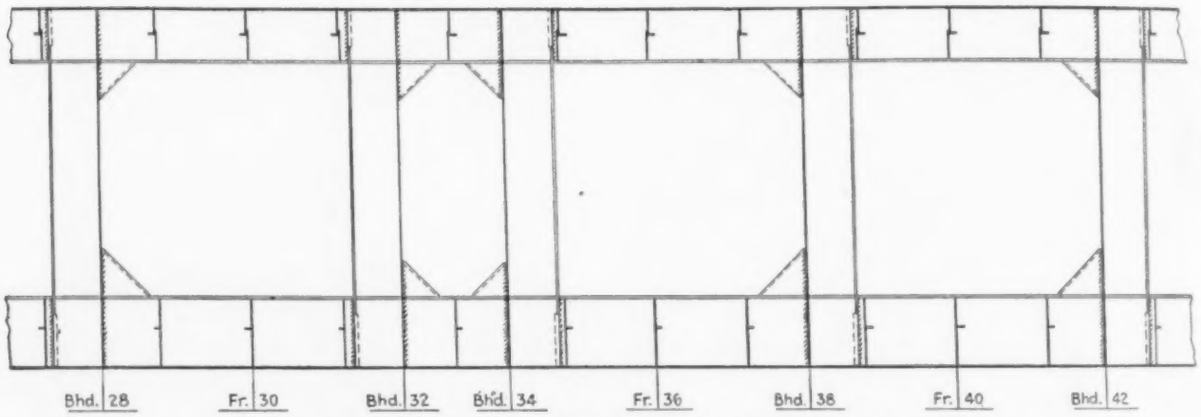


Fig. 7—Vertical Keel and Center Deck Girder. Shaded Lines Indicate Field Welds

heads in way of the transverse bulkheads. A few modifications from usual design were adopted, the principal being the use of heavy wrapper plates at the bulkheads, at the decks, bottom and side shell as illustrated in Figs. 4 and 5. In line with our usual practice, the longitudinal bulkheads are continuous, the transverse bulkheads intercostal, dividing the bulkheads into three pieces, none of which are too large or too heavy to handle in one piece. In welding a ship's hull the most important matters to be kept in mind are their great rigidity, possible loss of dimension due to shrinkage, possible distortion and/or residual locked-up stress.

As a tanker for the largest part of its length is practically a series of multiple units, that is, similar tanks, automatic machine welding of large shop assemblies insured maximum welding economy and fastest construction. In the past automatic machine welding using bare wire has been used to a very limited extent but immediately became obsolete with the advent of shielded arc electrodes for manual welding. There seems little prospect of successful application of multiple layer machine welding using shielded electrode to hull construction. Machine welding means starting at one end of a seam and welding continuously to the other end. Every shipyard welding engineer knows it is impossible to control distortion, shrinkage and residual stress using such an automatic process employing multiple layer deposition. Very thorough preliminary investigation indicated that the "Unionmelt" automatic process adopted for this work would solve this problem of distortion, shrinkage and stress. Actual experience has fully demonstrated that it does, at least so far as large shop assemblies are concerned. I mention the "Unionmelt" process because we adopted it. Other similar processes may be equally successful.

All the different parts of the structure were shop assembled in one tank length. The center keelson, rider plate and flat keel plate with the transverse brackets

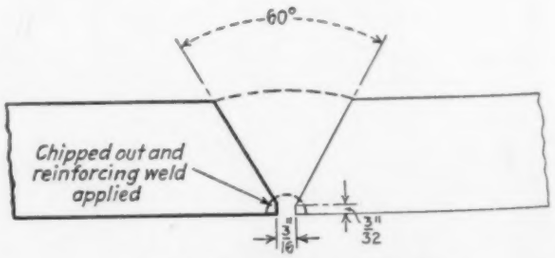


Fig. 8—Plate Edge Preparation for Manual Welds

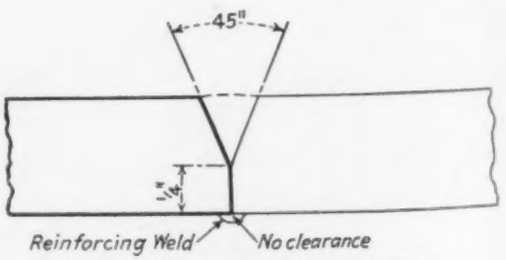


Fig. 9—Plate Edge Preparation for Automatic Welds

Fig. 10—Section Through Forward Portion of Shell

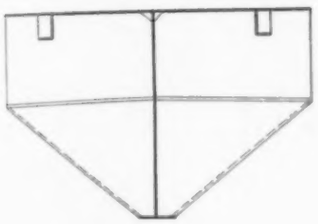


Fig. 11—Center Deck Girder Assembly

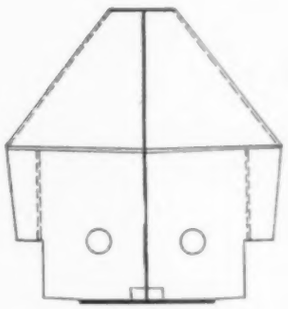


Fig. 12—Vertical Keel Assembly

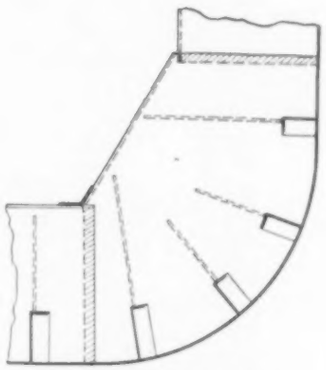


Fig. 13—Transverse Frame at Bilge

Fig. 12, was one assembly and manually welded. The center girder at the deck with center deck plate and transverse brackets, Fig. 11, was one assembly also manually welded. The bottom shell from the keel to the lower turn of the bilge together with one wrapper plate, longitudinal stiffeners and transverse web frames, Fig. 4, was one assembly. On this assembly the longitudinals and the shell longitudinal butts were machine welded, the transverses were welded to the shell manually. From the up-turn of the bilge to the sheer strake together with the bulkhead wrapper plate, transverses and longitudinals was one assembly. As in case of the bottom shell, each plate had three longitudinals and shell butts machine welded. The deck plating was treated in a similar manner and was in two assemblies on each side, one from the center-line strake to the inboard side of the longitudinal bulkhead, and the other from that point to the side of the ship, as shown in Fig. 5. The transverse bulkheads, as previously stated, were in three pieces, the center position and two wings, intercostal between the longitudinal bulkheads. All horizontal stiffeners and butts were machine welded, the webs, which were assembled with the bulkheads were manually welded.

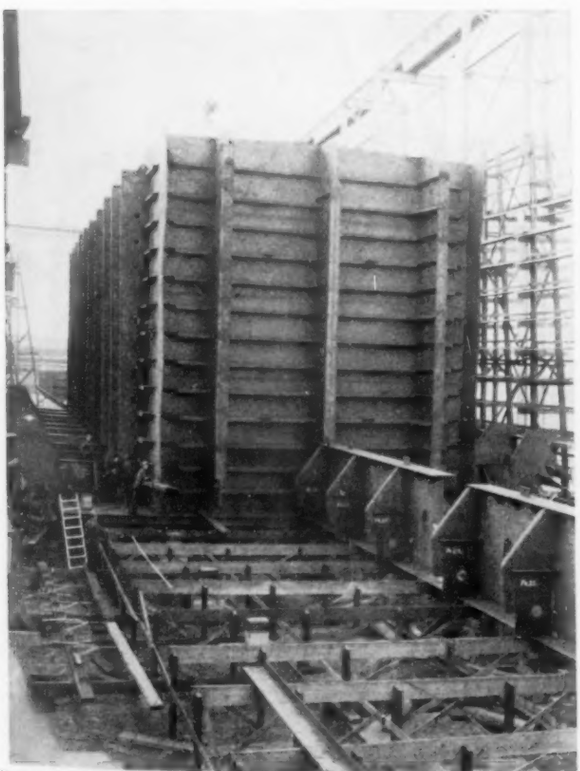


Fig. 14—Erection on Ways of 117-Foot Section Including Three Cargo Tanks and Pump Room Between Twin Longitudinal Bulkheads, Also Section of Flat and Vertical Keel

The longitudinal bulkhead final shop assembly was one tank length. Each plate was treated separately, that is, the longitudinals were machine welded to each plate and then the horizontal butts were machine welded. The vertical panel plates were then fitted and welded to the horizontal plates together with the overhanging longitudinals, which were all manual welded. This vertical panel plate, as will be noted, is joggled and overlapped onto the adjacent plates. This is the only overlap in the large assemblies. The reason for this was that this plate was originally intended to be welded to the transverse bulkhead, making it part of the bulkhead assembly; adjacent plates could then be bolted to the overlap in erection. This method, however, was found to be too cumbersome and was abandoned in favor of the assembly shown in Fig. 6 and photograph Fig. 15.

In preparing the parts for machine welding, the mill scale was removed from all faying surfaces. The longitudinal stiffeners were then placed in position on tacking table, left Fig. 1, dogged down and tack welded. The plate was then placed on welding tilting table, center Fig. 1, where a continuous fillet machine weld was deposited on each side of each stiffener. Adjacent plates were similarly treated. The plates with stiffeners already welded were rolled along the welding slabs to the butt welding machine, right Figs. 1 and 2. Here they were carefully alined, dogged down and the butts machine welded in one pass. Next they were transferred to the manual welding tables, extreme right Figs. 1 and 2, where the transverse web frames were fitted and welded by manual arc. Finally, the bulkhead wrapper plates were fitted and the vertical butts, together with the ends of

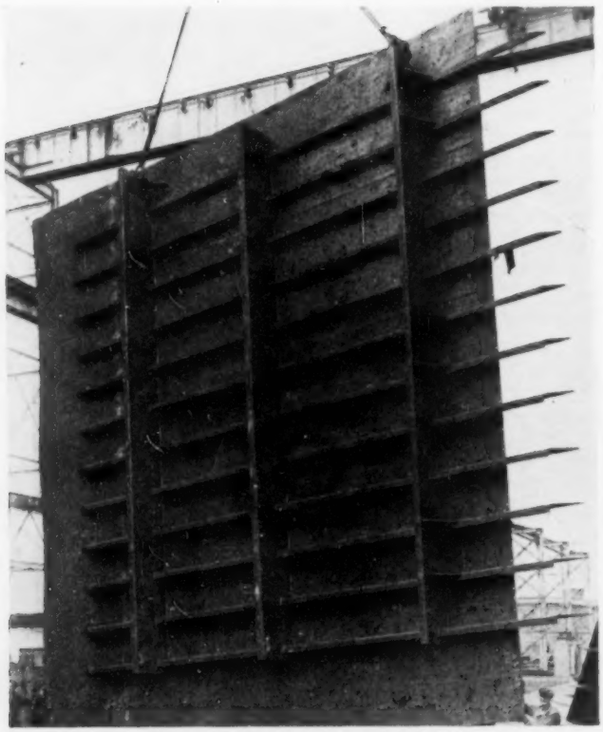


Fig. 15—Typical Section of Automatically Welded Longitudinal Bulkhead

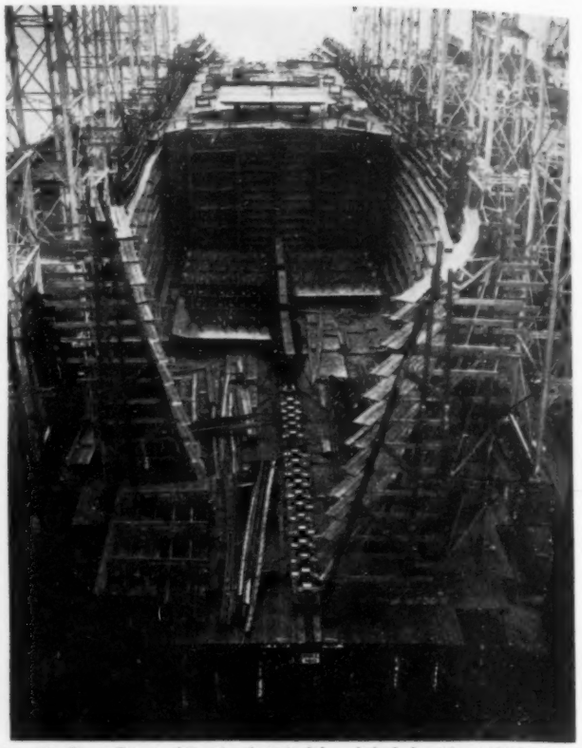


Fig. 17—Shows Extent of Erection Late in July. It Includes About 290 Feet Length of Cargo Tank Space and Engine Room

longitudinals which overhung the already assembled plating shown in Fig. 10, were hand welded, thus completing one assembled section. Shop assemblies of longitudinal and transverse bulkheads, bottom, deck and side shell were similarly made. Before final erection the opposite sides of all butts were reinforced, either by hand arc or portable automatic welding machine.

In erecting the assembled units, it was decided to start with a 117-foot section of the structure consisting of three cargo tanks, each 35 feet long, and a 12-foot pump room.

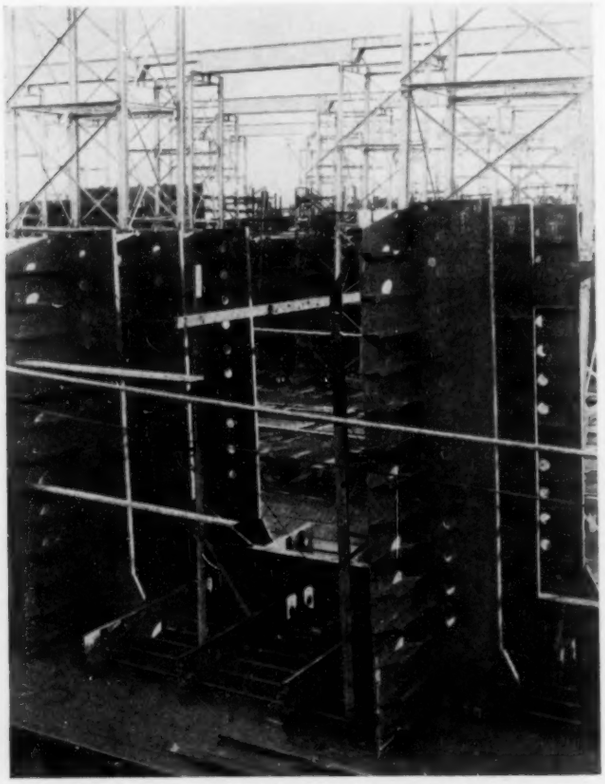


Fig. 16—Section of Bottom, Vertical and Two Transverse Bulkheads Assembled on the Ways

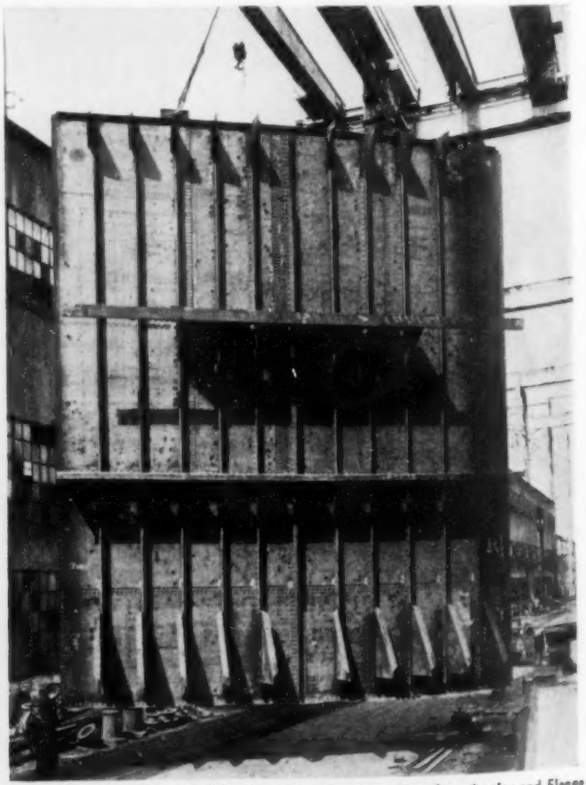
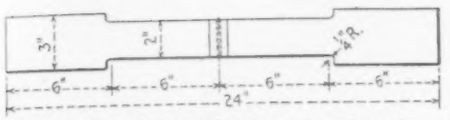
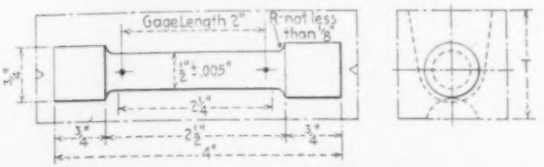


Fig. 18—Typical Riveted Bulkhead. Note Overlaps, Boundary Angles and Flange on Longitudinals and Web-Frames



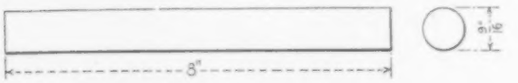
Two thus 1/4-1/2-3/4-1 inch ship plate. Two thus 1/4-1/2-3/4-1 inch parent plate (no weld).
Required result: Average tensile strength of weld specimens must be not less than 90 per cent of unwelded specimens.

TENSILE TEST, TRANSVERSE TENSION



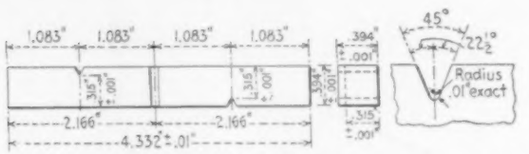
Two standard 0.505 inch specimens taken from weld metal in 3/4 or 1 inch plate.
Required results: Tensile strength not less than 56,250 pounds per square inch; ductility-elongation not less than 18 per cent.

TENSILE TEST, WELD METAL



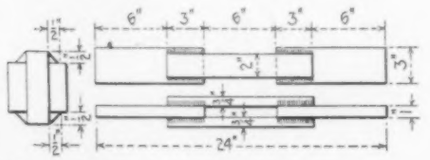
Two thus from weld metal in 3/4 or 1 inch plate.
Required result: Bend without fracture through an angle of 120 degrees over a bar 2 inches in diameter.

BEND TEST, WELD METAL



Note: Dimensions of "V" notches must be exact, especially radius at root of "V."
Two thus from weld metal in 3/4 or 1 inch plate.
Required result: Average value of each specimen not less than 20 foot-pounds

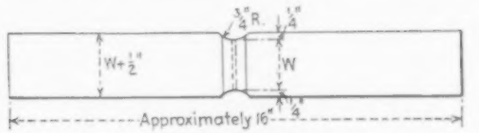
IMPACT TEST, ALL-WELD TEST



Two thus required.
Required result: Shear strength not less than 12,375 pounds per linear inch.

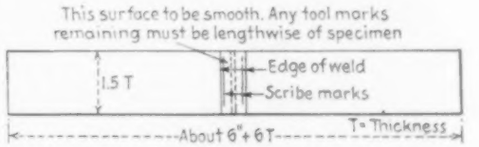
SHEAR TEST

Fig. 19—Lloyd's Arc Weld Test. Note: Chemical Analysis of Welding Rod Required

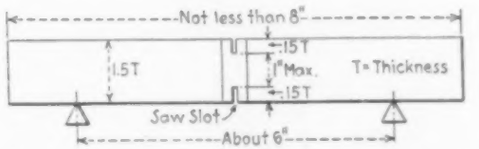


W = approximately 1.5 inches where thickness = 1 inch or less.
W = 1 inch where thickness is more than 1 inch.
Both faces of weld to be machined flush with the plate

REDUCED-SECTION TENSION SPECIMEN

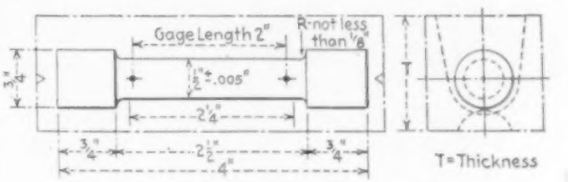

This surface to be smooth. Any tool marks remaining must be lengthwise of specimen
1.5 T
Edge of weld
Scribe marks
About 6" + 6T
T = Thickness

FREE-BEND SPECIMEN

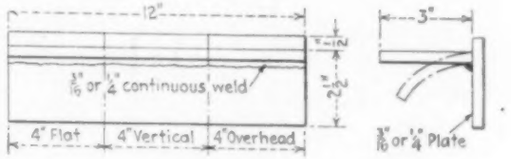


Do not remove weld reinforcement from either side of specimen. No machining required on this specimen

NICK-BREAK SPECIMEN



TENSILE SPECIMEN, WELD METAL



FILLET FRACTURE

Fig. 20— American Bureau of Shipping Arc Weld Test. Note: For Qualification of New Welding Process, an Izod Impact Test, Same as Shown for Lloyd's Test, Is Required

The erection was carried out in the following order. The first unit was the shop assembled flat and vertical keel, in one tank space lengths, with frame brackets attached as shown in Figs. 4, 7, 12 and photograph Fig. 14. This was followed by the complete bottom shell assemblies, from the flat keel plate to the lower turn of the bilge, port and starboard, in one tank space lengths, see Figs. 4 and 10. In connecting these assemblies to the flat and vertical keel, the bottom transverse frames were bolted to the frame brackets on the keel assembly and the seams of the flat keel and garboard strake were tack welded. Details of construction at the bottom of the webs on both the transverse and longitudinal bulkheads were arranged to permit the entire flat and vertical keel and bottom shell to be placed before any bulkhead was erected.

The complete amidship pump room was next placed in position, the assembly and erection being a modification of that used throughout the tank space. From the amidship pump room the erection was completed one tank space at a time in both directions from amidship.

For each tank space, the center section of one transverse bulkhead was first placed in position. By tack welding the middle bulkhead web to the vertical keel and by bolting the other webs to the bottom longitudinals the bulkhead was temporarily self-supporting. This was followed by the longitudinal bulkhead assemblies, port and starboard, as shown in Fig. 6, tack welded to the transverse bulkhead and bottom shell and bolted to the previous section of the longitudinal bulkhead. The webs on the longitudinal bulkhead at the frames were bolted to the bottom transverse. The center deck girder assembly, with the center strake of the deck and the frame brackets attached, as shown in Figs. 5, 7 and 11 were next hung between the transverse bulkheads. This unit was bolted to the middle transverse bulkhead web at one end and tack welded to the bulkhead plating at the other end. After sufficient temporary support was

Table 1—Automatic Weld Test—Hull Construction
Process Approval by Lloyd's Register and American Bureau of Shipping

P. Material—55,000 psi min.—Analysis. C-0.20 Mang. 0.43 Ph. 0.014, Sulph. 0.044

All tests in as-welded condition.

Transverse Full Tension (Lloyd)

Pl. Thick	Yield psi	U.T.S. psi	Failure
1/2 in.	34,600	58,100	In plate (2 in. or more from edge of weld)
1/2	38,800	58,200	In plate (2 in. or more from edge of weld)
3/4	32,700	68,500	In plate (2 in. or more from edge of weld)
3/4	29,200	60,100	In plate (2 in. or more from edge of weld)
1	27,900	55,500	In plate (2 in. or more from edge of weld)
1	29,400	59,700	In plate (2 in. or more from edge of weld)
Average	32,100	60,000	In plate (2 in. or more from edge of weld)

Required—Tensile strength—90% of unwelded specimen.

Tension Test Weld Metal (Lloyd)

Diam.	Yield psi	U.T.S. psi	% Elong. 2 In.	R.A. %
0.505	52,500	69,000	26.0	47.8
0.505	53,750	70,000	25.0	42.8
Average	53,125	69,500	25.5	45.3

Required—Tensile strength—min. 56,250 psi.
Elongation—min. 18%.

Bend Test Weld Metal (Lloyd) 9/16 in. diam. x 8 in. long
2 Specimens bent full 180°—sides flat together—no failure.
Required—120° without failure.

All Weld Metal Izod Impact 3 notch (Lloyd)

	Top Notch	Side Notch	Bottom Notch	Average
No. 1	36.5 ft. lb.	28.5	47.5	37.5
No. 2	33.5 " "	35	36	34.8
			Average	36.1

Required—Average value—min. 20 ft. lb.

Shear Test (Lloyd)

	Yield Pt. Actual	Yield Pt. P.L.I.	Ultimate St. Actual	Ultimate St. P.L.I.	Failure
No. 1	126,000	10,500	199,500	16,625	In plate
No. 2	113,000	9,420	183,500	15,300	" "

Lloyd requirement—12,375 Pounds per Linear Inch

Trans. Reduced Sect. Tension (A.B.S.)

Pl. Thick	Yield	Ult. Strength	Failure
1/2 in.	53,100	73,000	In Weld
1/2	52,100	72,700	" "
3/4	56,500	80,400	" "
3/4	54,000	79,700	" "
1	47,850	69,700	" "
1	45,900	76,000	" "
Average	51,575	75,250	" "

Required—Min. 60,000 psi.

Free Bend (Weld at Center of Specimen) A.B.S.

1/2 in.	50.5% elong. in weld	(no failure—bent flat)
1/2	45.1 " " " " " " "	
3/4	54.0 " " " " " " "	
3/4	56.5 " " " " " " "	
1	29.7 " " "	(no failure at 25% Specimens broken for exam.)
1	23.7 " " "	(no failure at 22% Specimens broken for examination at request A.B.S. surveyor)

Required—20%

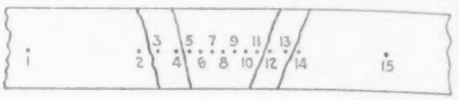
Nick Break (A.B.S.)

1/2–3/4–1 in. PI—good penetration—no gas or slag inclusions—silky fracture.

Fatigue (Not required by Lloyd or A.B.S.)

Endurance limit 45–55% of ultimate strength.

Hardness Test (Not required by Lloyd or A.B.S.)



Location	3/4 in. Thick Coupon R.B.	3/4 in. Thick Coupon Brinell	1 in. Thick Coupon R.B.	1 in. Thick Coupon Brinell
1	84.0	162	73.0	132
2	82.0	156	70.0	125
3	81.0	153	73.5	133
4	81.5	154	74.0	135
5	79.5	149	77.5	142
6	79.0	147	75.0	137
7	79.5	149	80.0	150
8	80.0	150	81.0	153
9	79.5	149	78.0	144
10	80.0	150	79.0	147
11	80.5	151	77.5	142
12	79.0	147	74.5	136
13	79.0	147	74.5	136
14	74.0	135	73.5	133
15	73.0	132	70.0	125

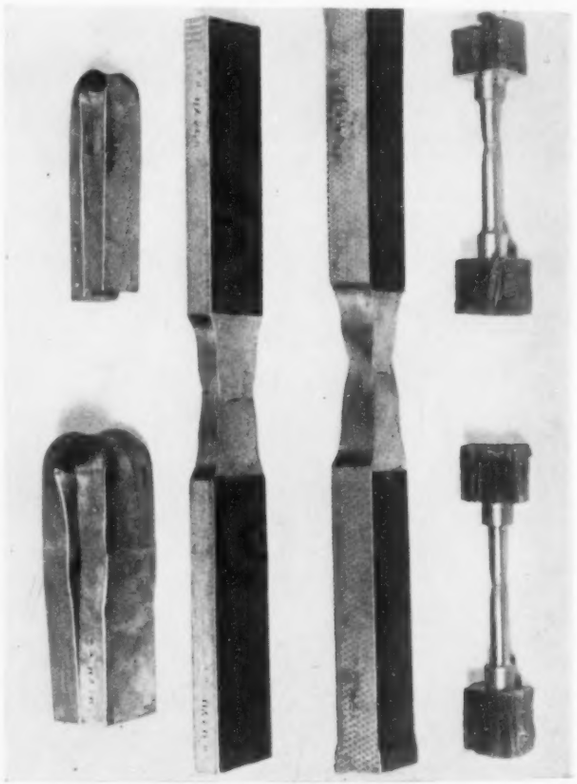


Fig. 21—Free-Bend, Reduced-Section Tension and All-Weld-Metal Tension Test Specimens Prepared from 1 and 1 1/2-Inch Welded Plates

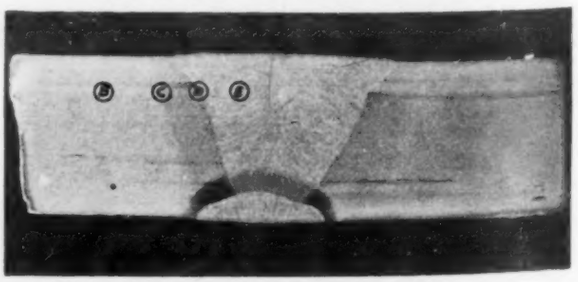
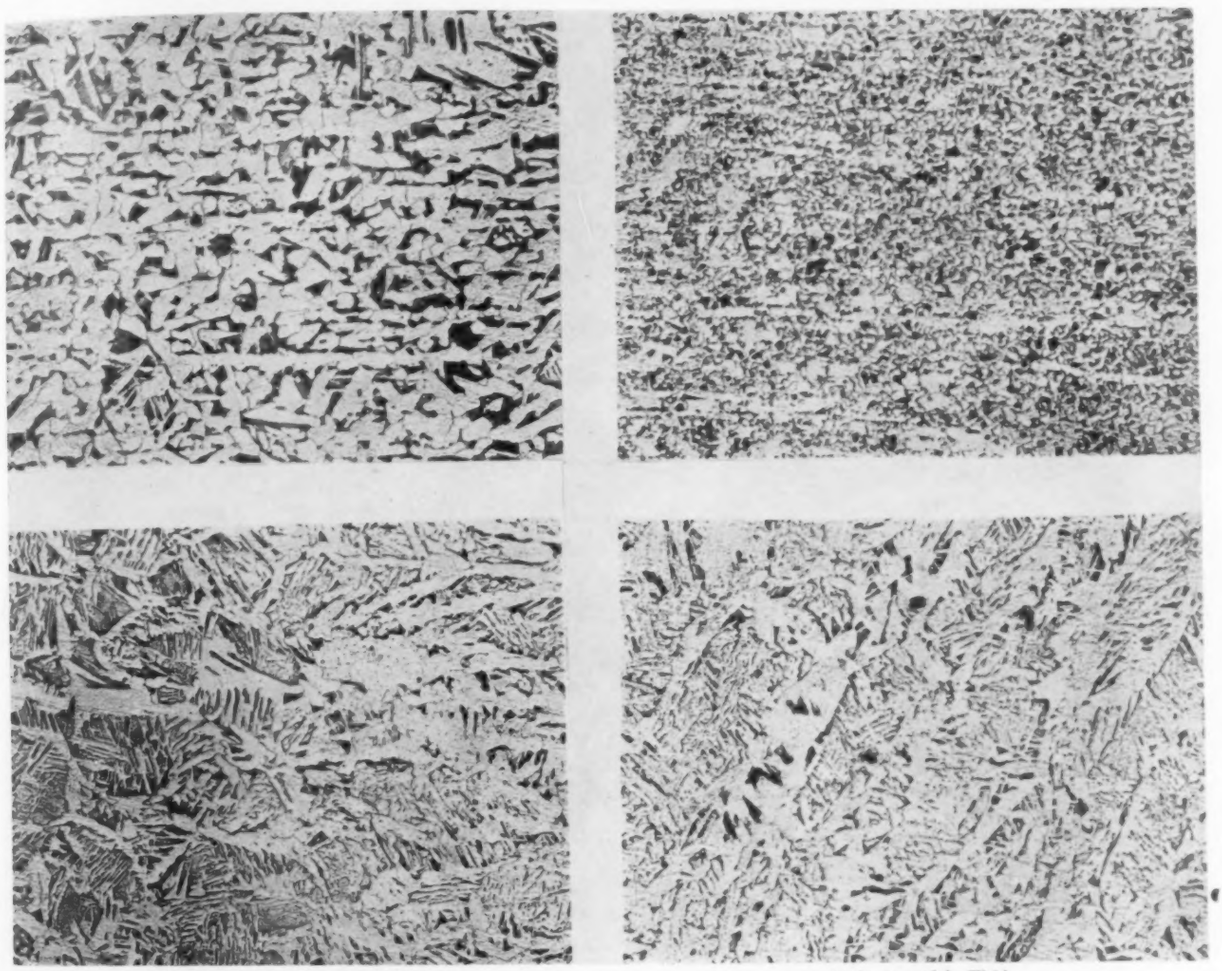


Fig. 22—Macro-Etched Section of Weld in 1-Inch Plate

B—Grain Structure in Plate

C—Heat-Affected Zone in Plate



D—Heat-Affected Zone Near Weld

E—Structure of the Weld

Fig. 23—Photomicrographs Taken at Locations B-C-D-E in Fig. 21

placed under the center girder, the two side center deck assemblies, see Fig. 5, were placed in position. The transverse beams on these sections were bolted to the frame brackets on the center girder and to the frame brackets previously welded to the longitudinal bulkhead.

The two outboard sections of the transverse bulkheads were next erected, the erection of these being similar to that of the center line section of this bulkhead. The bilge plates were not assembled in the shop. These were left until completion of all erection and were the closing plates of the entire unit. After the outboard section of transverse bulkhead was erected, the bilge brackets, see Fig. 13 and photograph Fig. 14, were next put in place and bolted to the transverses erected with the bottom shell. This was followed by the erection of the bilge longitudinals. The side shell plating along with the transverses and one wrapper plate, as shown in Fig. 5, were next erected in position, the lower part of the transverses connected by bolts to the bilge brackets already in place, and tack welded to the wing transverse bulkheads. The outboard deck section shown in Fig. 5, along with the transverses which were bolted to the frame brackets already in place, completed the 117-foot unit.

As previously stated, the bilge strakes were the closing plates and were lifted from the ship. Before final welding was started, the vessel was well shored, aligned and checked for length, which was found to be exactly 117 ft.

The sequence of final welding the now assembled unit was as follows: The flat keel seams throughout, port and starboard simultaneously were first welded, followed by the longitudinal bulkhead connection to the bottom shell. The transverse bulkhead connection to the bottom shell out to the lower turn of the bilge was the next procedure. Following this all transverse butts in the bottom shell plating, including the butt of the flat keel, were welded. Then the overlap of the bottom shell longitudinals on the bottom shell were welded in place. Following this the transverse bulkhead to the longitudinal bulkheads were next welded. The deck plating was next welded, concluding with the welding of the side shell.

In the welding of all butts the back-step method was used. In the case of the flat plate keel, for instance, two welders worked on each seam, port and starboard simultaneously, working away from the center toward the ends, back-stepping the welding. By so doing, distortion and shrinkage were reduced to a minimum.

In welding the main units both automatic machine welding and manual arc welding were employed. At present, automatic welding is used only on shop assemblies. The manual arc is used on shop assemblies where use of the automatic machine is impracticable; it is also used on the shipways to weld together the assembled sections.

The automatic Unionmelt process being used has sev-

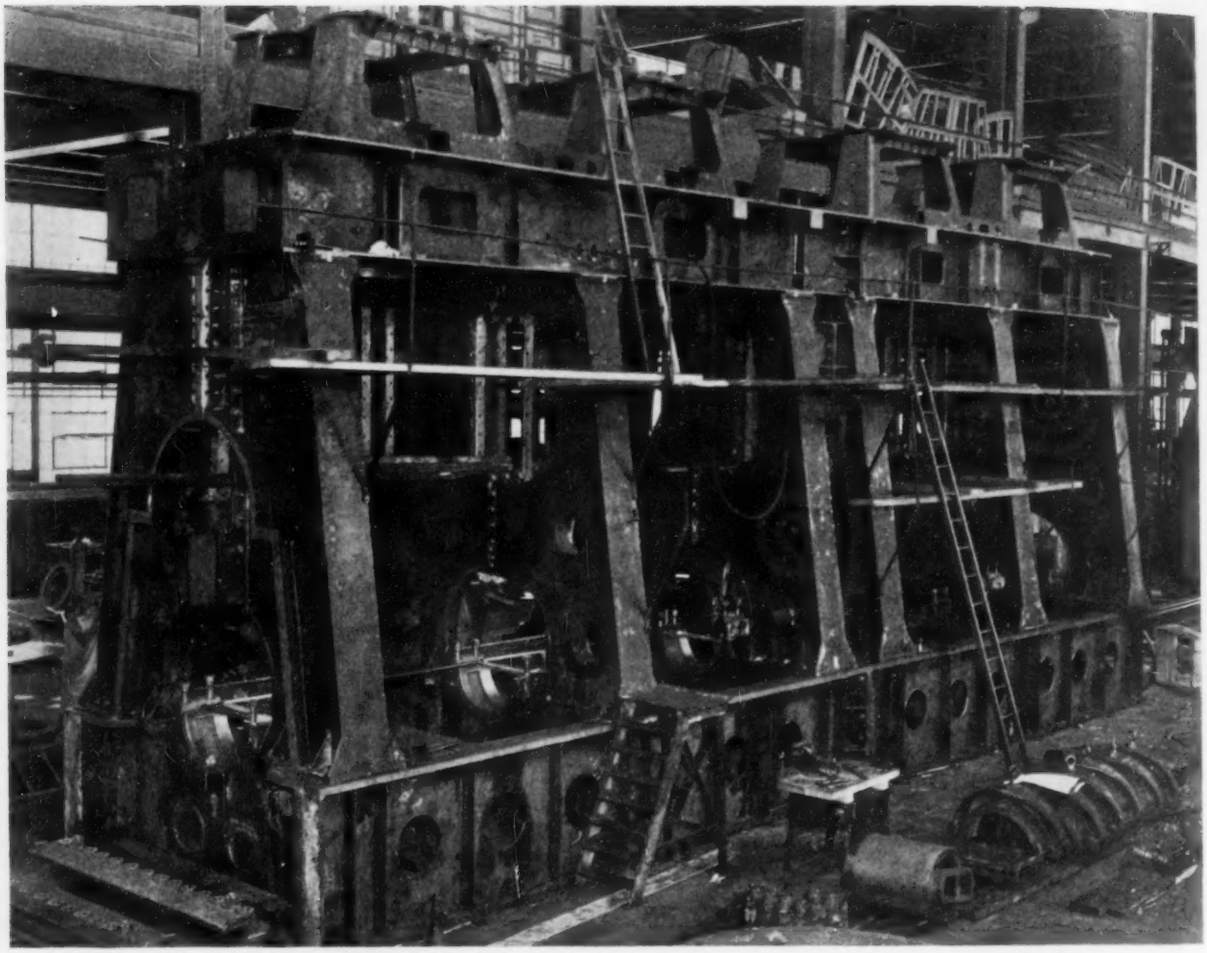


Fig. 24—5000 Horsepower Sun Doxford Diesel Engine

eral very marked advantages. It speeds up production, greatly minimizes residual stress and distortion, it practically eliminates loss of dimension due to shrinkage, insures uniformity and protects the weld from atmospheric contamination. The effect of this protection is evident in the physical test results given in this paper. The Unionmelt process is not an electric-arc process in the usual meaning of that term; resistance fusion more correctly describes it. It is well known that mineral compounds or mixtures will conduct electric current when in the fused or semi-fused condition. In this process the fused melt carries the current with a resistance which corresponds to a voltage of from 25 to 50 volts depending upon the voltage regulation effected by the con-

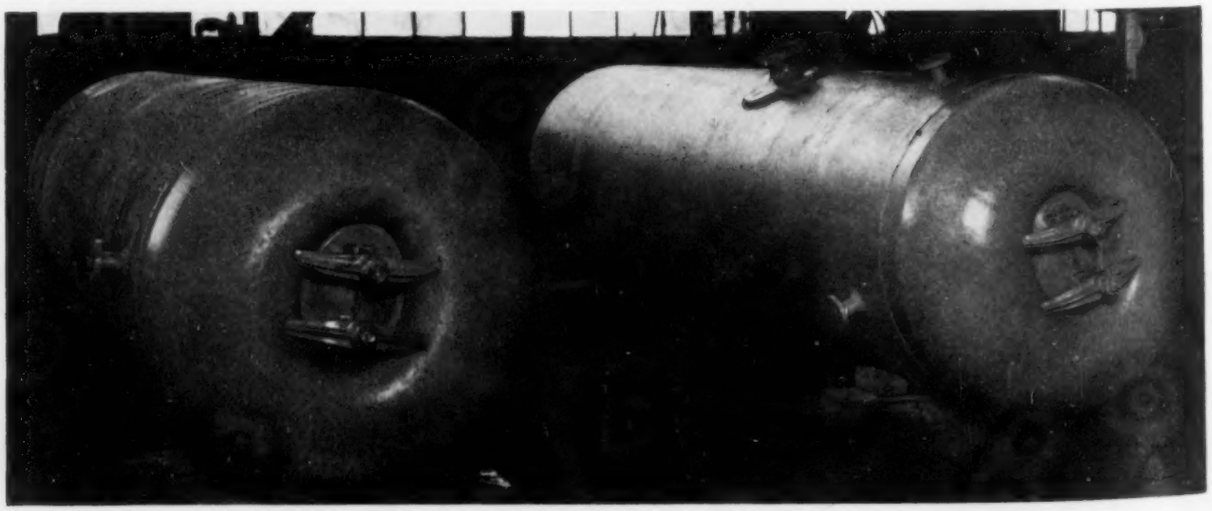


Fig. 25—Welded High-Pressure Air Storage Tanks, 1 1/4-Inch Plate

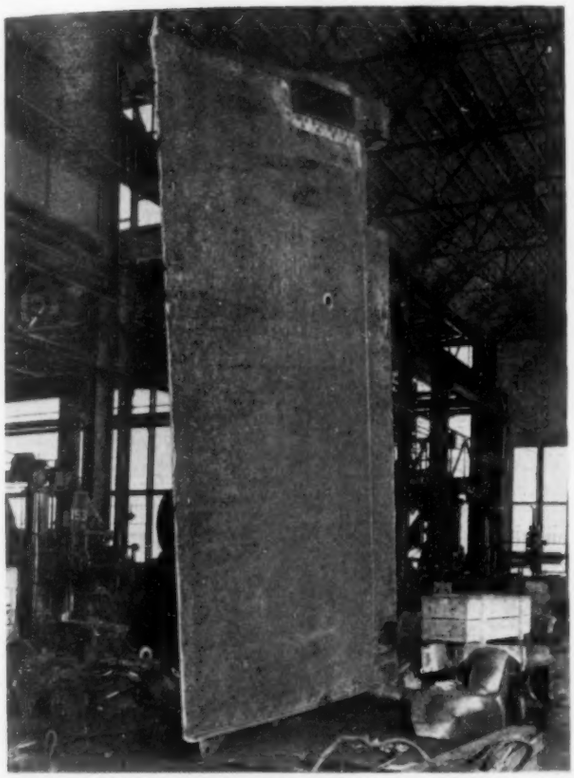


Fig. 26—Ship's Rudder—Combination of Steel Castings and Plate Welded. Weight Saved About 10%

trol mechanism. The release of electrical energy, due to the resistance of the fused melt, provides the heat for making the weld.

The sequence of welding sub-assemblies on the ways has already been outlined. Manual arc welding, using heavily coated electrodes, is so well known that no description is necessary except to emphasize that the technique employed in depositing weld metal, the size of electrodes and the current values used as well as the sequence of welding assemblies together, it is believed, will result in a minimum residual stress, distortion and shrinkage.

Figures 1 and 2 show the automatic welding machine layout designed to utilize the Unionmelt process in welding shop assemblies. Reference has already been made to sequence of operations employed. Figure 3 is a close-up view of the tilting table with welded head, etc., in welding position.

Figure 14 shows extent of the erection of the first 117-foot section on the ways early in April. It consists of three cargo tanks and a pump room between twin longitudinal bulkheads. It also shows bilge brackets and longitudinals and a section of flat and vertical keel. Figure 16 shows a section of bottom, vertical keel and two transverse bulkheads. Figure 17 shows extent of erection late in July. It includes about 290 feet length of cargo tank space and engine room.

The above illustrations show fair lines almost entirely free of distortion or warping. Careful check at this time showed less than $^3/_4$ inch longitudinal and less than $^1/_2$ inch transverse shrinkage which is due to greater amount

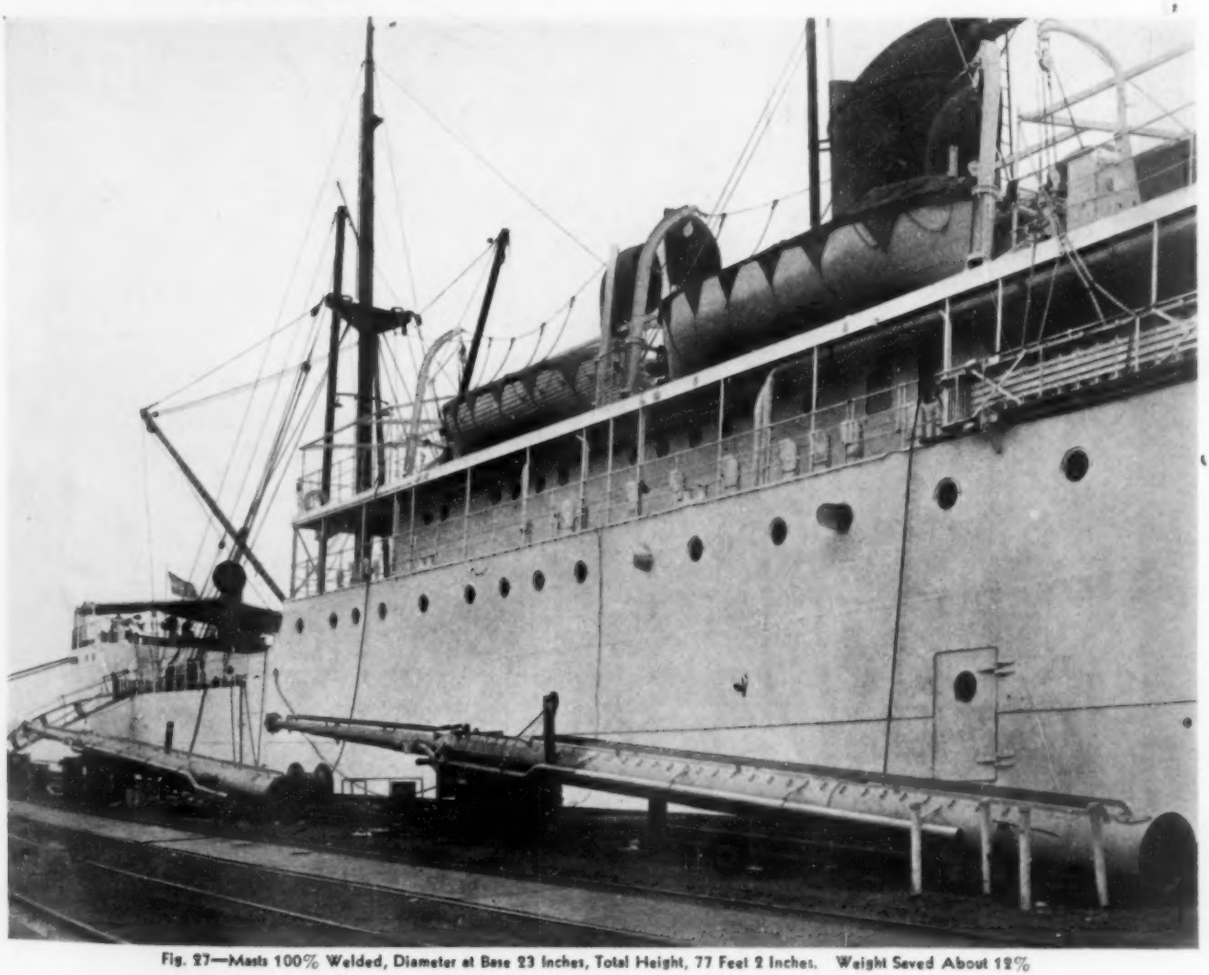


Fig. 27—Masts 100% Welded, Diameter at Base 23 Inches, Total Height, 77 Feet 2 Inches. Weight Saved About 12%

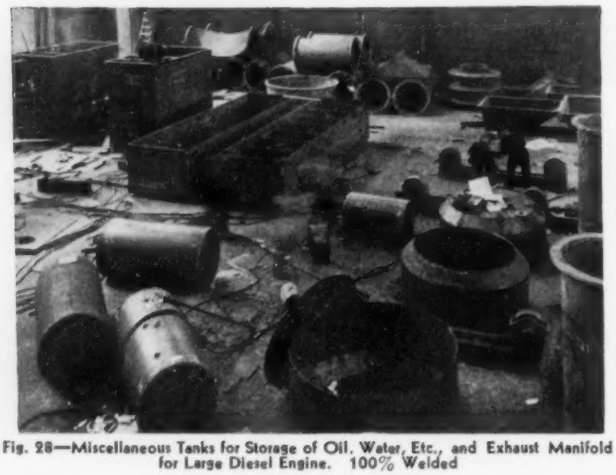


Fig. 28—Miscellaneous Tanks for Storage of Oil, Water, Etc., and Exhaust Manifold for Large Diesel Engine. 100% Welded

of manual field welding at the after-shaped end. There was no evidence of vessel raising from the keel blocks.

Figure 18 shows a typical riveted bulkhead. Note the plate overlaps at the seams, the boundary angles and the flanges on longitudinals and web-frames, all of which are eliminated with welded construction. The saving in weight of steel in the welded hull due to such items for the entire hull structure, as noted above, is about 15%.

Table 1 shows the result of a combination test made on $^1/_2$ inch, $^3/_4$ inch and 1 inch thick plates butt welded for approval of the automatic procees by Lloyd's Register of Shipping and American Bureau of Shipping. Test specimens are shown in Figs. 19 and 20. It will be noted that all test results are well above the minimum requirements of both societies. They reveal a combination of tensile strength, ductility, impact value and endurance limit for welds tested in "as-welded" condition which is noteworthy. Figure 21 shows the specimens after test.

Figure 22 is a macro-etched section of weld in a 1 inch thick plate. Photomicrographs taken at locations B, C, D and E are shown in Fig. 23. These show grain structure in the plate, heat-affected zone in the plate, heat affected zone at edge of weld and the structure of the weld, respectively. The hardness test table shows exceptional uniformity in the plate, through the heat-affected zone and the weld. While photomicrographs show coarse grain structure in the single-pass weld, the test results and illustration of test specimens shown previously present ample proof of sufficient strength, ductility, impact value and endurance limit for hull construction. In fact, all test values more than meet the requirements of the A. S. M. E. Power Boiler and Unfired Pressure Vessel codes for welding boiler drums and pressure vessels for any service.

The following photographs will show, to some extent, the application of welding to machinery and other structures separate from the hull proper.

Figure 24. 5000 horsepower Sun Doxford Diesel engine. Use of steel shapes, plates and steel castings welded together, in place of cast-iron construction, has resulted in a stiffer, stronger structure, with a saving in weight of about 120 tons, more than 30%. Welding on this structure by Lukenweld, Inc.

Figure 25. Welded high-pressure air storage tanks $1^1/_4$-inch plate. Built to practically same requirements as A. S. M. E. Power Boiler Code.

Figure 26. Ship's Rudder—combination of steel castings and plate welded. Weight saved about 10%.

Figure 27. Masts 100% welded, diameter at base 23 inches, total height, 77 feet 2 inches. Weight saved about 12%.

Figure 28. Miscellaneous tanks for storage of oil, water, etc., and exhaust manifold for large Diesel engine. 100% welded.

Conclusion

It is our opinion that operating results, maintenance costs and saving in weight will more than justify the extra expense, if any, necessary to weld vessels and equipment as outlined in this paper. Ultimately welding must lead to a somewhat different shop layout and a somewhat different yard personnel, as it is not a strenuous operation, it requires skill rather than brawn.

Discussion Annual Meeting Papers

No Stenotype Reporter

Members desiring to discuss papers are urgently requested to prepare discussion in writing in advance of the meeting and to send copies to headquarters as those preparing written discussion will be given preference at the sessions. Members and guests giving extemporaneous discussion at meeting should forward a written transcript of discussion as soon as possible after the meeting.

Assembly Plant for the Welding of Barges*

By GEORGE F. WOLFE†

THE Engineering Works Division of the Dravo Corporation, located on Neville Island in the Ohio River ten miles below Pittsburgh, Pa., has been engaged in the building of floating equipment for a period of twenty-five years. The fabricating plant and launching ways on Neville Island were designed to accommodate riveted construction but the transition to welded construction has caused many revisions in the plant, the latest and most modern of which is a complete assembly plant for mass production of welded hulls.

The standard practice of ship construction on the inland rivers is to erect a vessel in position directly over the launching ways and, after completing all yard assembly in this position, launch same sideways into the river. Heretofore the work has been done out-doors and, in the case of welded vessels, is subject to more delays due to weather conditions and in general may require more time than does riveted construction, which in busy periods adds to the congestion of equipment on the launching ways. A careful study of production methods led to the adoption of an assembly line method and a completely housed operation. A two-bay building of all-welded construction was erected, the building consisting of one main bay of 91 ft. 6 in. span for erection of vessels, and

*To be presented at Annual Meeting, A. W. S., Atlantic City, Oct. 18–22.
†Chairman, Welding Committee, Engineering Works Division, Dravo Corporation.

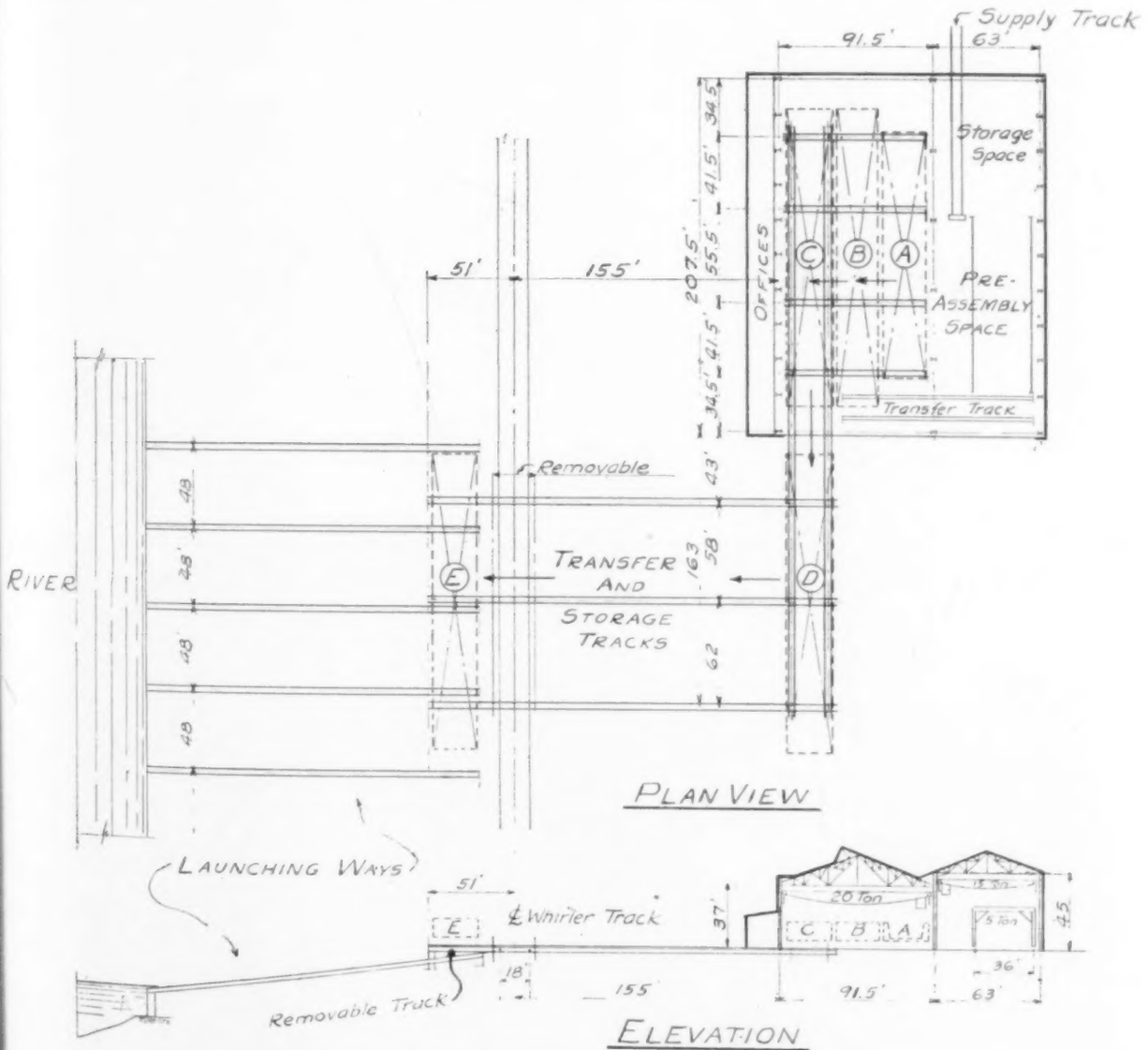


Fig. 1—Plan View and Elevation of Barge Assembly Plant and Launching Ways

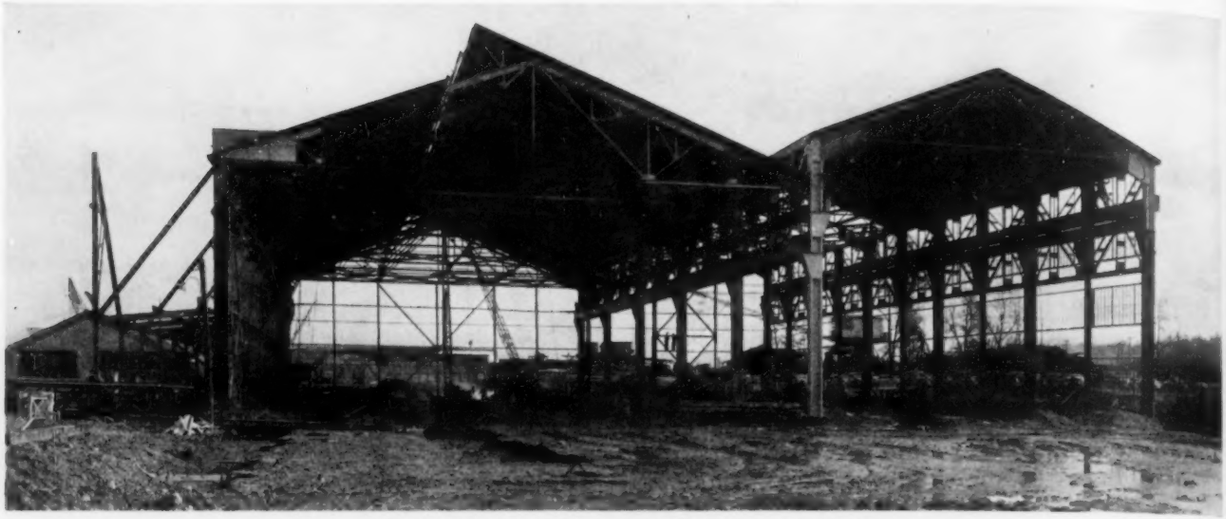


Fig. 2—Erection View of Two Bay All-Welded Barge Assembly Shop

a side bay of 63 ft. 0 in. span for receiving and storage of materials and for preliminary assembly operations.

Figure 1 shows the plan view and elevation of the assembly building with respect to the launching ways. The building is shown in the upper right-hand corner and the letters "A," "B," "C," etc., designate the various positions of a vessel as it progresses to completion. The heavy double lines indicate the system of transfer tracks used to bring the vessel to its final launching position at point "E."

Figure 2 shows a construction view of the two-bay building before the side walls were added. In the design of the building rolled beams were used where possible; all columns consist of 24-inch I-beams with the center line reinforced with 18-inch channels while the crane girders are of 27-inch I-beams with channels for side stiffening. The roof trusses were built up of angle sections, except that for the top chord a 24-inch I-beam was split to form a 12-inch deep Tee section.

All vessels are fabricated in the main Structural Shop and then brought to the assembly plant in as large pieces as can be conveniently handled and received in the 63-foot bay. Designs for welded construction have progressed for several years and include the development of an improved all-welded coal barge, of which seventy (70) were built last year. This barge lends itself particularly to this method of assembly. It is a barge of the hopper type, 175 ft. long x 26 ft. wide x 10 ft. 8 in. deep. The sides consist of box sections about 3 ft. 0 in. wide, 10 ft. 8 in. deep and 30 ft. 0 in. long, weighing about 10 tons each. Figure 3 shows one of these side box sections as it leaves the Structural Shop. The side frames in these box sections are pre-assembled and welded as one operation in jigs and are then assembled with the plating to form the box section. All overhead welding is eliminated by turning the box section over once during the welding operation. The interior of the box sections are painted by spraying before they enter into the final assembly. Five such sections form one side of the main body of the barge with similar box sections at the corners of the rake ends.

The bottom of the barge is framed transversely with special serrated angle sections made by splitting channels on an irregular line and welding these sections to flat

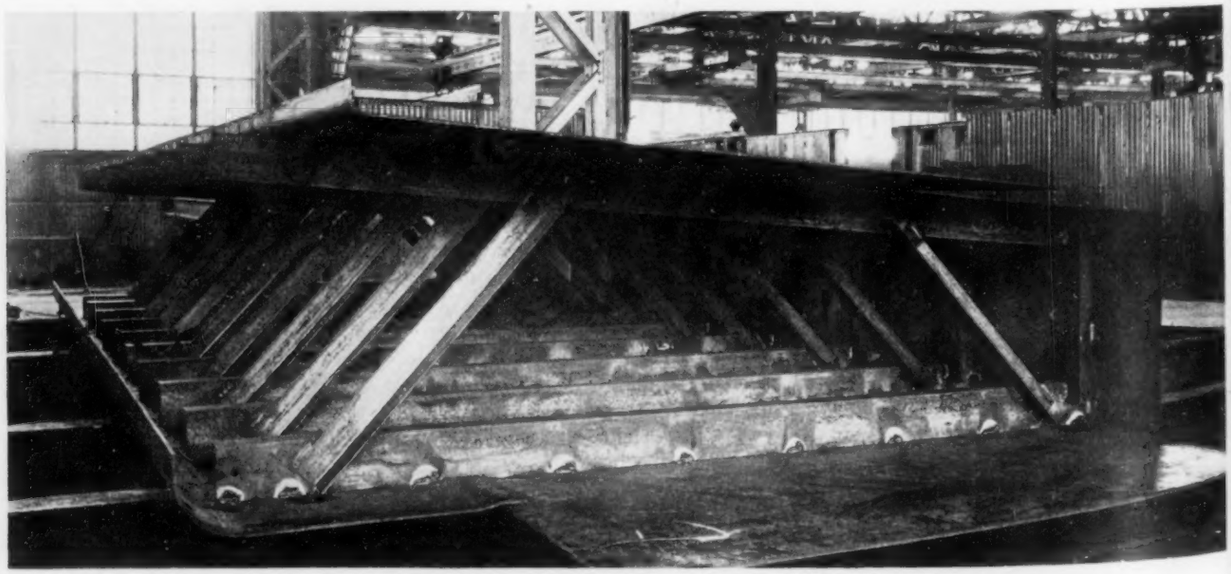


Fig. 3—Shop Assembled Side Section Unit of Welded Coal Barge

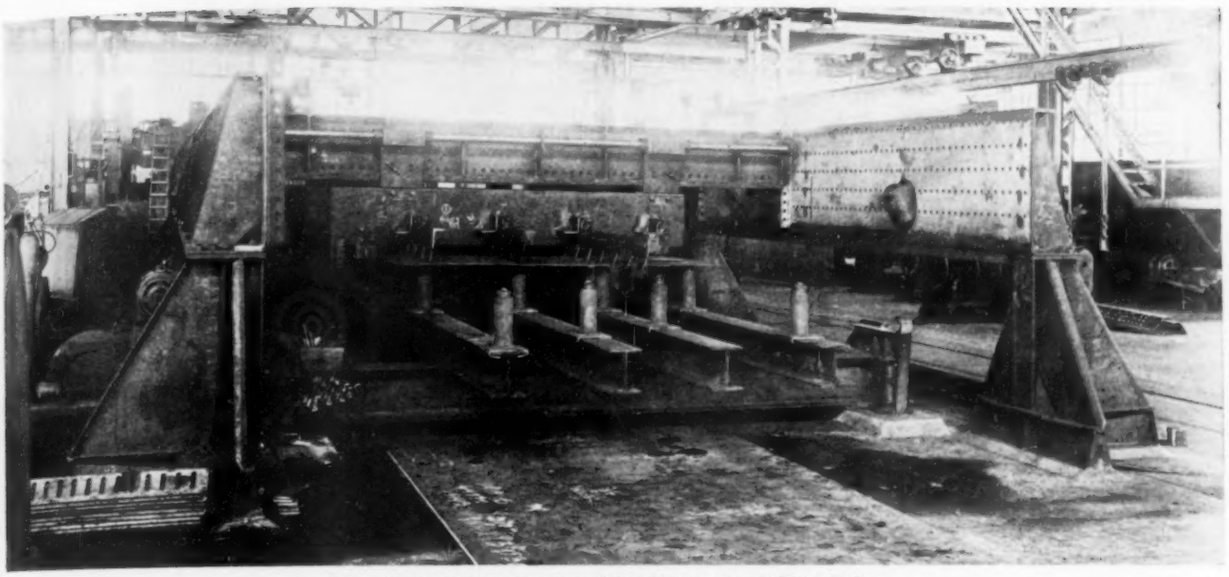


Fig. 4—Tacking Serrated Channels to Bottom Plates on Special Fitting Table

plates. A special fitting table, as shown in Fig. 4, was developed to automatically space and hold the angle sections during the assembly and tacking operation. The flat plate is entered into the jig over a series of roller casters which are supported on a beam framework which is raised by hydraulic jacks. The angle sections are entered into slots in the cross spacing beams prior to raising the bed by the jacks which clamp the entire assembly into position for tacking. The tacked assembly is taken from the fitting jig to tilting tables as shown in Fig. 5, where the section is positioned at about 45 degrees and the angles are welded to the plates by a continuous bead running entirely around that portion of the web which contacts the plate. After the welding is completed on one side of the connection, the table is tilted through an angle of 90 degrees for the welding of the opposite bead.

The rake frames are assembled in the Structural Shop by jigging. Corner section assemblies, similar to side box sections, are also made before transfer to the assembly plant.

Fig. 5— Bottom Plate and Serrated Channel Assembly on Tilting Table for Welding

The erection of the barge is started in position "A" by laying down the bottom plates with floor beams assembled and setting thereon the ten box sections comprising the sides. The supporting structure for blocking the barge during assembly in this position "A," as well as in positions "B," "C" and "D," consists of permanent steel supports, as shown in Fig. 6, at the proper level for

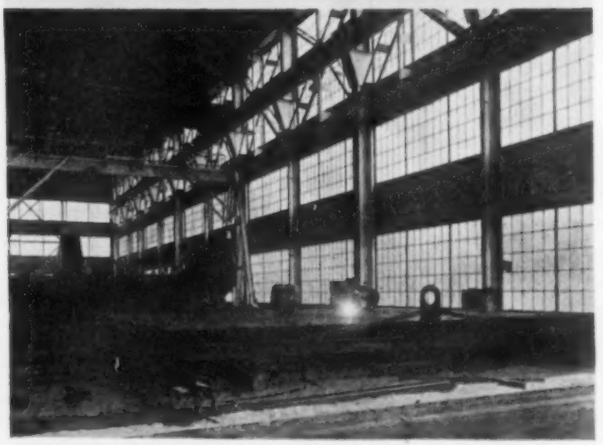


Fig. 6 (Top)—Permanent Steel Supports and Transfer Trucks in Erection Bay
Fig. 7 (Bottom)—Pre-Assembly of Bottom Plate Sections & Rake End at Preliminary Operation in Side Bay

Fig. 8—Welded Transfer Carriage Equipped with Four 15-Ton Hydraulic Jacks

convenient access for welding underneath. The bottom-plate sections, which come from the Structural Shop in 8 ft. x 25 ft. pieces, are pre-assembled in the side bay, as shown in Fig. 7, into sections having a transverse width of 25 ft. and a length of 40 ft. by welding together five of the 8 ft. wide assemblies. Lap joints are used and the entire assembly is turned over in order to secure downhand welding throughout. After the bottom plates and side sections are in position all sections are brought into proper alignment, tack welded and the entire main body of the barge, weighing approximately 100 tons, is lifted from the blocking by means of hydraulically operated jacking and transferring carriages located on the four transverse transfer tracks and moved over into position "B."

The transfer carriage, shown in Fig. 8, was given careful study before the final design was adopted as it represents the backbone of the entire handling operation. The all-welded framework is carried on four 18-in. solid wheels $4^1/_2$ in. in width which were cut out of rolled steel billets. The two lifting beams of the carriage, to which the cushioning timbers are attached, are raised by means of four 15-ton hydraulic jacks actuated by oil under pressure produced by a hand pump. During the transfer of barges at and beyond position "C" the change of direction of travel is secured by lowering the barge a few inches and supporting same on the permanent steel blocking and then continuing the lowering of the lifting frame until it is about four inches in the clear below the barge. The entire carriage is then lifted by means of a roller bearing swivel hydraulic jack at the center of the carriage which engages a concrete pier located at the intersection of the tracks. As soon as the carriage is lifted sufficiently so that the wheels are out of the track groove the carriage is turned by hand through a 90 degree horizontal angle and the change of direction is accomplished. The barge is again raised by means of the main lifting jacks and is now ready to be moved in a direction at right angles to its former line of motion.

The power for the moving of the assembled barges from positions "A" to "B," "C" and "D," as shown in Fig. 1, is furnished by two single drum electric hoist engines acting through a wire rope system. One engine located at the extreme right side of position "A" serves for the transverse movement to positions "B" and "C" while the second engine located under position "B" serves to move the finished vessel from position "C" to "D." A similar hoist is located at the head of the launching ways to move the barges from position "D" either into the storage space or directly to the launching ways.

In position "B" the rake ends, which have been completely assembled in the 63 ft. bay, are brought in and attached to the main body of the barge and any loose plates necessary for complete closure are added. The majority of the final welding is done in this position and the barge is then moved over to position "C," where any remaining welding is completed. The barge is now tested for water-tightness by filling the various tanks with water after which all interior and exterior painting is completed. The barge which now weighs 150 tons is

Fig. 9—Barge in Position on Launching Ways After Transfer from Hydraulic Carriages

Fig. 10—Launching Is an Excellent Test of the Welding

raised on the transfer carriages and taken out through the end of the building, which is equipped with sliding doors to permit opening the entire width of the building, to position "D," where the direction of the movement is again changed to transverse and the vessel is carried to position "E" where the transfer tracks overlap the launching ways sufficiently to enable the transfer of the vessel from the transfer buggies to the regular launching skids as shown in Fig. 9. The vessel is then launched sideways into the river in the usual manner with the customary splash, as shown in Fig. 10, and comes to rest ready for immediate service.

Building Up Locomotive Driving Boxes*

By IRVING T. BENNETT†

END play liners on locomotive driving boxes have, in the past, been a source of trouble and expense to many railroads. These liners, commonly called hub liners, are designed to take the end thrust of the driving boxes against the wheel hubs.

Suitable provision must be made in locomotive design to allow sufficient lateral or clearance between the face of the driving box and the hub of the driving wheels in order to permit the locomotive to easily round curves, take cross-overs and otherwise accommodate momentarily misalignment of the driving wheels.

Such liners are subject not only to considerable friction but also to impact loads, which momentarily may reach high stress values.

In the past it was more or less standard practice in the railroad industry to cast standard bearing bronzes on the hub face of the driving boxes, depending upon dovetails, insert pins and other mechanical means for the proper fastening of the liner. Such methods produced a mechanical joint of uncertain value, particularly due to the fact that the bronzes employed, for the most part, possessed high shrinkage values. Moreover, the particular alloys used, while possessing good anti-frictional properties, lacked malleability and had poor resistance to pounding or impact loads.

The combination of a poor mechanical fit, together with the inherent lack of ductility very often resulted in service failures. It was not uncommon to require liner replacement several times between classified repairs. Liners would work loose, crack and fall out. Replacement was expensive, not only in labor and material but, furthermore, caused a hidden expense of considerable magnitude, depending upon the time the locomotive would be out of service, due very often to this one condition.

A careful study of the problem indicated the need for the liner to be securely fastened to the face of the box and also pointed toward the necessity of employing a metal of high physical values more suited to resisting shock and wear. It was natural, therefore, to consider the use of welding to affix the liner permanently to the surface of the steel box.

Through the courtesy and assistance of the New York Central Railroad Company, a test program was planned. One set of tests called for building up the entire face of the box by means of the electric arc, employing materials later described. A second test consisted of placing a plate of rolled metal on the face of the box and suitably welding same thereto. A third series consisted of placing suitably designed segments of rolled material welded to the surface of the box on their edges and to each other.

In undertaking this experimental program, several alloys were carefully investigated, the physical properties

* To be presented before the AMERICAN WELDING SOCIETY, Eighteenth Annual Meeting, October 18–22, 1937, Atlantic City, N. J.

† Revere Copper and Brass Incorporated.

Table 1—Relative Physical Properties. Herculoy and Other Metals Used on Steam Railroads

Metal	Condition	Rockwell Hardness 60 Kg.-1/16 Ball	Uultimate Tensile Strength Lb./Sq. In.	Percent Elongation*	Impact Izod Ft.-Lb.
Herculoy	Soft Rod	91	63,000	72	..
	Drawn Rod	105	72,000	50	..
	Cast	90	51,500	70	55
Leaded herculoy	Cast	83	46,800	56	15
10% phosphor bronze	Cast	90	51,700	18	3 1/2
10% phosphor bronze leaded	Cast	85	45,900	16	3 1/2
80 Cu. 10 Sn. 10 Pb.	Cast	83	39,600	9 1/2	3
88 Cu. 10 Sn. 2 Zn.	Cast	90	44,300	10	7 1/2

* % in 2 inches.

determined and a study made of the weldability of these alloys, coupled with an estimation of their wearing properties, particularly after deposition by the electric arc.

Table I shows the physical properties of the metals considered. The ease of weldability, high physical strength and high resistance to impact, lead to the selection of Herculoy, an improved silicon copper alloy of the following analysis:

Copper	96.00%
Silicon	3.50%
Tin	0.50%

Silicon is very efficacious in improving physical characteristics, its effect being several times that of tin.

For purposes of comparison, test bars were made from cast material, as this was considered better practice since the arc deposited metal was essentially in the cast condition.

It will be noted that the Herculoy possessed the best combination of high physicals and hardness with high impact values.

It was expected that any of the methods employed would result in a liner which would remain permanently attached to the surface of the box, possess good wearing properties, extend service mileage and eliminate entirely the need of repair or replacement at the frequent intervals previously encountered when the old cast method was employed. The results of these tests were very positive in character and the accompanying tabulation (Table 2) indicates the wear found on the various boxes after 114,202 miles of service operation, which mileage on this particular railroad is that usually encountered between back shop repairs.

It will be noted that the boxes built up entirely by means of the electric arc performed as well as the boxes on which the plates and segments were used. The use of the electric arc provided a very flexible and versatile method of accommodating all sizes and shapes of boxes with a minimum amount of inventory and, consequently, it was decided that this method was best adapted to the solution of the particular problem.

Further tests provided satisfactory checks and, as a consequence, the New York Central Railroad adopted this practice as standard throughout their system.

Table 2—Performance of Herculoy for Hub Faces on Locomotive Driving Boxes

Three methods were decided upon:

1. Building up the face of the box by fusing Herculoy rod with the electric arc.
2. A solid liner plate of Herculoy welded to the box face.
3. A series of segments of Herculoy welded to the box face.

The above three methods were tried on the driving boxes of a J-1 type locomotive. Periodic check-ups were made during the regular quarterly inspection periods, and final inspection was made when this locomotive was unwheeled and made ready for shopping. The mileage was 114,202 miles. The following tabulation is self-explanatory:

Designation of Driving Box Applied Metal, Herculoy	Front R-1	Front L-1	Main R-2	Main L-2	Rear R-3	Rear L-3
Form	Rod-arc Built All Way	Rod-arc Built All Way	Solid Plate Welded On	Solid Plate Welded On	Segments Welded On	Segments Welded On
Measurement from jaw face to box face (inches)						
Original	2 19/32	2 19/32	2 21/32	2 21/32	2 19/32	2 19/32
Final	2 19/32	2 9/16	(See Note)	2 19/32	2 9/16	2 19/32
Liner wear at point above jaws (inches)	0	1/32	...	1/16	1/32	0
Approximate liner wear at top of hub face (inches)	1/8	1/8	...	7/32	1/16	3/32
General appearance of liner face	Excellent	Excellent	...	Excellent	Excellent	2 Segments Missing

NOTES:

General Appearance of Wheel Hubs — In every case, hubs were unmarked, bright and shiny; no evidence of cutting or galling. The main box, right side, was taken out of service November 26, 1934, due to hot crown brass. The rear box, left side, lost two segments. On this box segments were welded on edges only.

CONCLUSIONS:

1. From tests, observation and service, it is felt that Herculoy is ideally suited to application for locomotive hub liners.
2. It is possible to expect service from such liners from "shopping" to "shopping."
3. The rod method seems best adapted to this problem, although segments are satisfactory if welded on edges and middle.
4. Economies of considerable magnitude may be expected because of continued operation, also to the fact that but little work is necessary to resurface.

Fig. 1—Dovetailed Driving Bar

Fig. 2—Typical Cast Hub-Liner Failure—Note How Left Portion of Liner Has Slipped Around After Cracking. Right, Tip Is Also Missing

Further metallurgical developments were made whereby substantial amounts of lead were included in the deposited metal. Lead, present as such, materially improves the machinability of the deposits and, further, aids the anti-frictional properties of the alloy.

It was previously considered impractical to permit lead to be present in a welding rod and, in fact, all manufacturers' specifications very stringently covered this point by holding permissible lead in welding and brazing rods to only a trace. By the development of a proper welding technique, it was found possible to arc deposit alloys containing as high as 15% or more of free lead, although in commercial application the lead content is less than this. The use of the electric arc, particularly the metallic arc, results in very uniform dispersion of the lead throughout the alloy; in fact, the uniformity is better than that commonly found in cast material.

Certain machining tests were conducted on driving boxes, in which surface speed as high as 265 feet per minute were used, which value is considerably in excess of normal machining requirements on a job of this character.

In an application of this kind, welding speed, coupled with well bonded metal, was of paramount importance. One of the novelties of this work lies in the fact that metallic electrodes up to $^5/_8$ inch diameter have been employed, although $^1/_2$ inch diameter is most commonly used, except on the Baltimore and Ohio, where $^3/_8$-inch coiled rod is employed.

Experience has proved that the best procedure for applying Herculoy is with the metallic arc, using reverse polarity. Table 3 shows recommended practice

Fig. 3—Arc Deposited Hub Liner Before Finish Machining

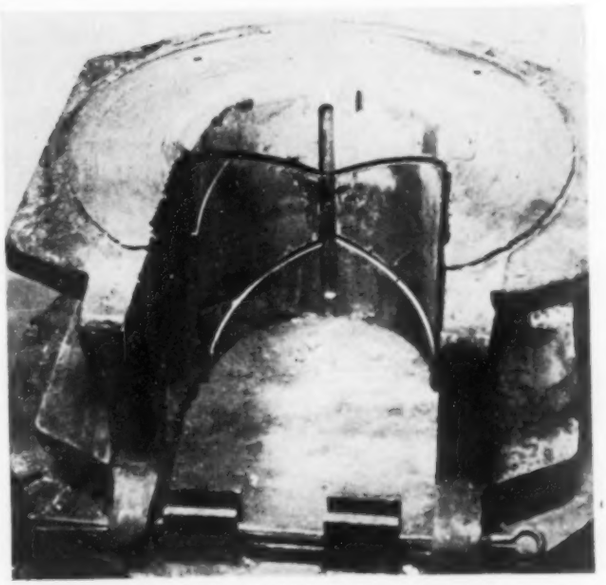


Fig. 4—Typical Hub Liner Returned from Service for Rewelding. Entire Liner Is Present—Wear Is Uniform—115,000 Miles Service

Table 3

Procedure:

Rod Size	Metallic Arc Current Value	(Reverse Polarity) Closed Circuit Voltage
3/8 inch	450	30–35
1/2 inch	600	30–35
5/8 inch	750	30–35

Rod Size	Carbon Arc Carbon Size	Current	(Direct Polarity) Voltage
3/8 inch	5/8 inch	450	40–45
1/2 inch	3/4 inch	600	40–45
5/8 inch	1 inch	750	40–45

The metallic arc is more fool proof, in the hands of inexperienced operators, than the carbon arc. It is true that larger amounts of metal can be melted down with the carbon arc, but it requires proper technique and training to insure a proper bond of the metal so deposited. The bond with the metallic arc is inherent with the process.

When using either process, suitable electrode holders must be employed and the operator protected with suitable clothing. Provision should also be made for the removal of welding fumes, since the large current values cause some volatilization of the metal.

Study was made covering the effect of varying rates of deposition on the character of the deposited metal, the efficiency of the deposition, spatter losses incurred and other pertinent factors. Tables 4 and 5 show certain of the data developed.

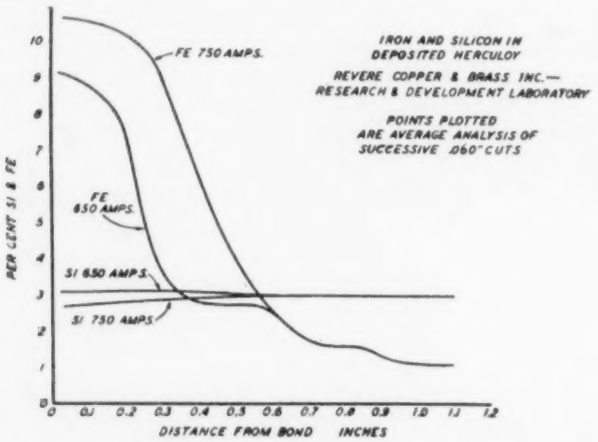

IRON AND SILICON IN DEPOSITED HERCULOY
REVERE COPPER & BRASS INC.— RESEARCH & DEVELOPMENT LABORATORY
POINTS PLOTTED ARE AVERAGE ANALYSIS OF SUCCESSIVE .060" CUTS
FE 750 AMPS.
FE 650 AMPS.
SI 650 AMPS.
SI 750 AMPS.
PER CENT SI & FE
DISTANCE FROM BOND INCHES

Fig. 5—Iron and Silicon Variation in Arc Deposited Herculoy. Samples from Actul Driving Box

In conducting the deposition-rate studies shown, considerable difficulty was experienced in getting results that would be consistent as to the time and rate of deposition when using the carbon arc, whereas with the metallic arc, it was possible to duplicate the results very closely from test to test.

The operation of the carbon arc depends greatly upon the operator's technique, and, if a firm bond is made to the underlying steel, the time required is about the same as when using the metallic arc. If it is just a question of seeing how much rod can be melted, the time is very much decreased by the use of the carbon arc, all of which is clearly shown on the tabulation.

Some apprehension was felt by certain engineers regarding the structural changes taking place in the cast steel surface of the box during a welding operation proceeding at high speed and with high current values. A box was prepared in the normal method and, after deposition, cut transversely into a number of sections which were carefully polished and checked for cracks and structural changes in the steel. Furthermore, analyses were made at various intervals to show the distribution of the silicon through the deposited metal, as well as to determine the extent to which iron migration occurred during the welding operation.

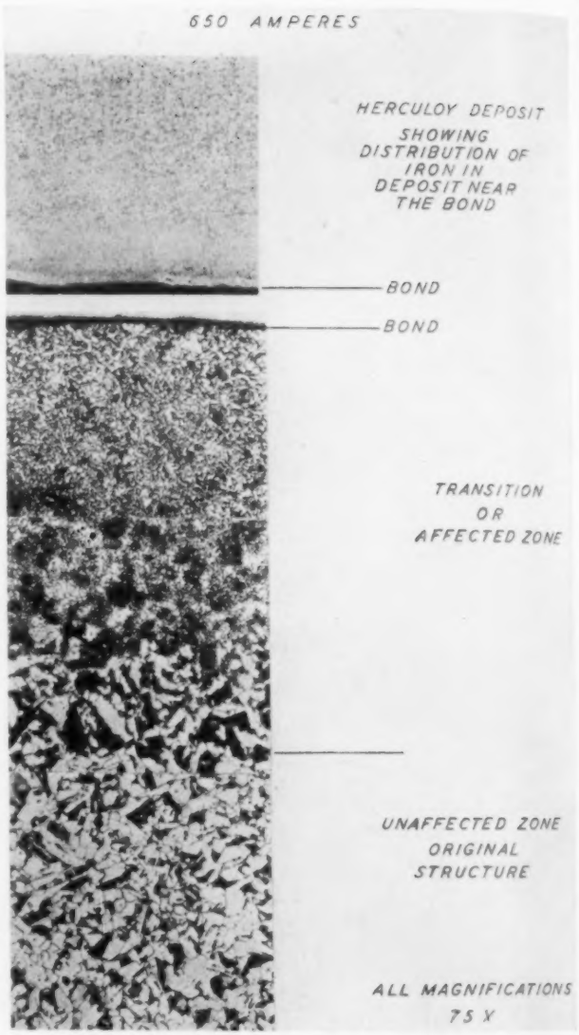


Fig. 6—Micro-Section Through Welded Driving Box

A detailed study of the steel surfaces disclosed no sign of cracks. There is a continuous gradation of temperature away from the bond, which produces a consequent gradation of grain sizes in the affected zone. Original structure is found about 3/16 inch from the bond. The photomicrographs show representative structures and not the entire area of change.

Molten steel migrates into the deposit while it is molten and varies from near 10% at the bond to 1% one inch from the bond. The steel is fairly evenly distributed, as shown by micrographs and chemical analyses. The silicon content of the deposit is not affected to any great extent by the welding process.

Time permits only a brief outline of the work actually done at certain railroad shops. The General Electric Company, in cooperation with the Baltimore and Ohio Railroad, developed an automatic arc welding head, using a 3/8-inch electrode in coil form. This automatic head is attached to a fixture similar to a small radial drill with a swing arm around the vertical column, which

Table 4—Lead-Coated Herculoy Fusion Rods Time Studies

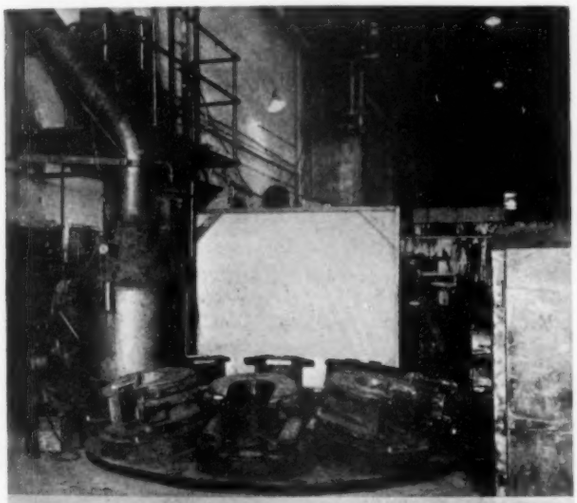
Diameter of Rod	Amperes	Volts	Electrodes Used on 1-Hr. Operation (Lb.)	Comments
1/2 inch	450	30	34.4	Good appearance
	550	35	45.0	Good appearance
	700	35	53.0	Good, but too hot
	800	40	62.0	Fair—too hot

Actual time to completely weld a J-1 driving box (dovetailed type):

Rod	Amperes	Volts	Actual Time	Amount of Metal Used (Lb.)
1/2 inch	550	35	78 min.	46.5
1/2 inch	700	35	55 min.	40.0
5/8 inch	800	35	65 min.	51.0

On one of the complete boxes, a machine cut of 1/4 in. was taken, and then it was resurfaced in one pass, using 1/2 in. by 24 in. rod at 600 amps., 35 volts. Actual time was 15 minutes, and weight of rod used was 9 lb.

Fig. 7—New York Central Set-Up. Driving Boxes Are on Turntable with Ventilating Hood at Left



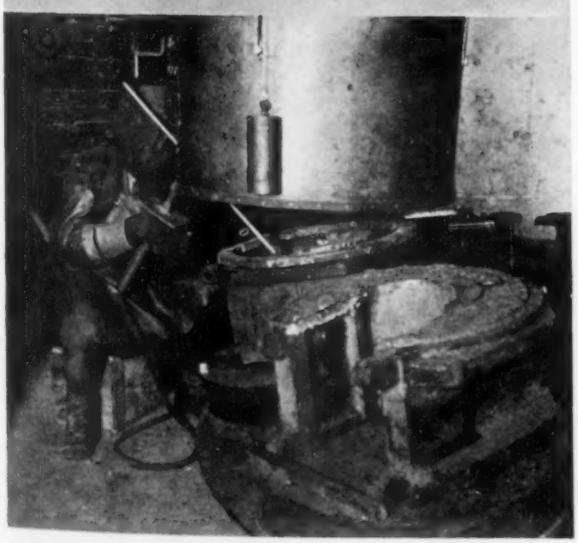


Fig. 8—Driving Box Positioned for Welding. Operator About to Strike Arc. Note, Copper Lined Restraining Ring in Position, Also 10 Degree Slope on Boxes

provides a horizontal adjustment and may be used by the operator to start his weld either from the inside or outside diameter of the box surface. The deposit may

Fig. 9—Partially Welded Box Viewed Over Welder's Shoulder. Backing Ring, Crown Brass and Asbestos Dams in Place

be as much or as little as desired, depending upon the regulation of the equipment. Under the swinging arm and adjacent to the column, the driving box is positioned upon a rotating table properly regulated to time itself with the feed of the electrode through the automatic head. In dealing with new boxes, the surface is suitably sand blasted, following which the Herculoy is deposited to any required dimension. It is stated that a new box can be built to full liner dimensions in approximately one hour. Boxes previously arc welded and requiring only one layer to compensate for lateral wear are welded in approximately twenty to thirty minutes. It is stated that mileage obtained before requiring lateral repairs ranges as high as 120,000 to 150,000 miles, a great deal,

Table 5—Deposition Rate Study Lead-Coated Herculoy Rods

Process	Rod Diameter	Amperes	Volts	Lb. Rod Per Hour Used	Lb. Rod Per Hour Deposited	Per Cent Spatter Loss	Lb. Dep. per Kwh.
Metallic arc	5/8	380	30	28.49	27.79	2.43	2.44
		450	30	35.76	34.17	4.17	2.53
		500	30	38.72	36.72	5.16	2.45
Metallic arc	1/2	500	30	43.10	41.30	4.17	2.75
		600	30	46.69	44.39	4.92	2.47
		700	33	54.99	50.57	8.04	2.19
Metallic arc	5/8	700	33	62.46	57.78	7.50	2.50
		800	35	66.00	57.60	12.72	2.06
Carbon arc	1/2	500*	42	47.96	47.96	0	2.28
		500†	42	97.68	97.46	0.2	4.64
		600*	42	65.25	65.25	0	2.59
		600†	42	128.13	127.84	0.2	5.08
		700*	45	139.04	138.72	0.2	4.40
Carbon arc	5/8	700†	45	156.47	156.03	0.3	4.95

NOTE:
* Metal fused to base to insure good bond.
† Metal simply melted down in carbon flame and puddled.

of course, depending on the class of service and the territory in which the locomotive is performing.

The New York Central Railroad apply their material by means of the metallic arc manually operated.

An interesting and effective method of handling boxes was developed by their engineers. Eight boxes are mounted on a revolving turntable, so the welding operation is practically continuous. While the welder is at work, his helper can unload previous boxes and mount the ones to be welded. Each box on the turntable can also be rotated and is mounted at an incline of 10° with the horizontal. This permits "up-hill" welding, which is quite essential, due to the large current values employed, and permits the arc to work on new surfaces by preventing the mass of molten metal running ahead of the point of contact.

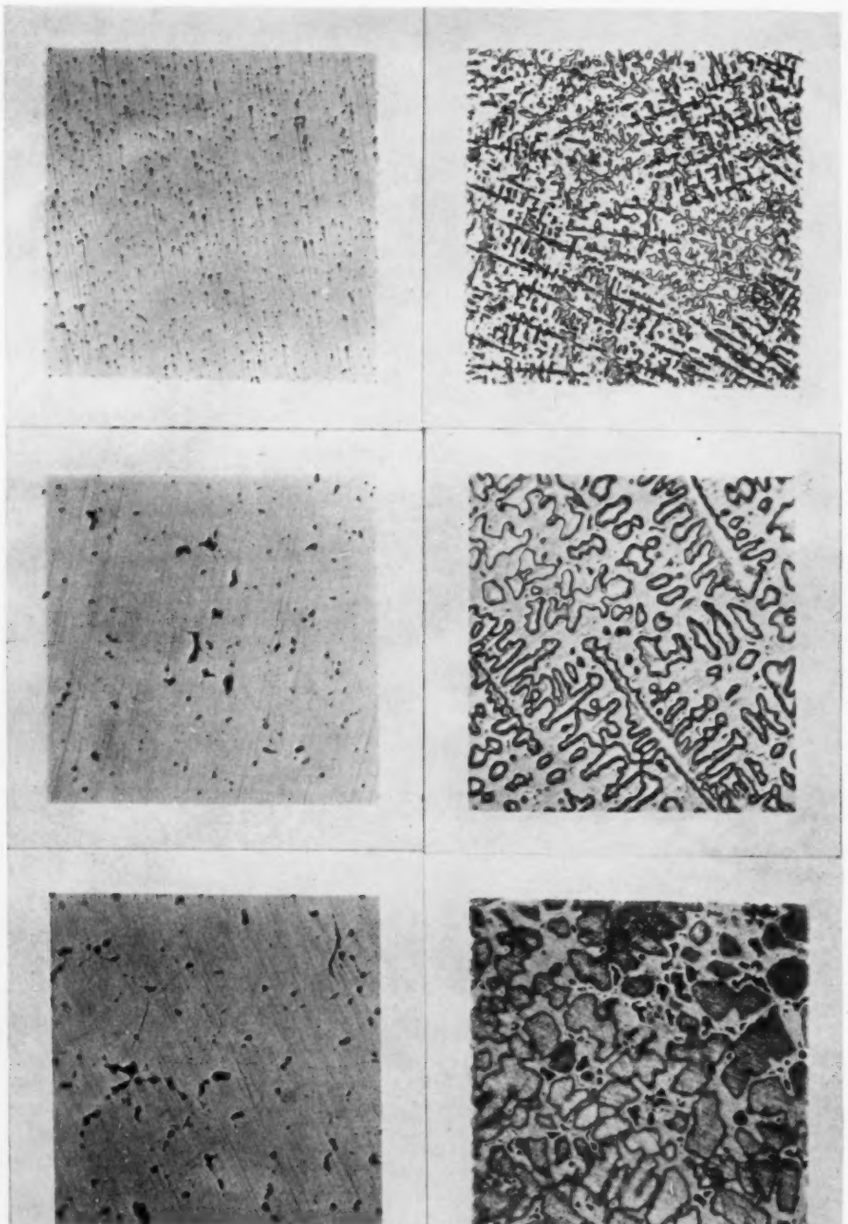


Fig. 10—Arc Deposited Bearing Bronze (85 Cu—5Pb—10 Sn) Showing Lead Distribution as Unetched—75 Diameter

Fig. 13—Arc Deposited Bronze Etched to Show Structure Same Composition as Fig. 10 75 Diameters

Fig. 11—Sand Cast Bearing Bronze Unetched—75 Diameters Same Composition as Fig. 10

Fig. 14—Sand Cast Bronze Etched to Show Structure Same Composition as Fig. 10 75 Diameters

Fig. 12—Oxyacetylene Deposited Bearing Bronze Unetched—75 Diameters Same Composition as Fig. 10

Fig. 15—Oxyacetylene Deposited Bronze Same Composition as Fig. 10 75 Diameters

Photographs Reduced to 2/3 Size

A counter-balance is provided for the rod holder and an exhaust applied over the box being welded.

A copper-faced steel ring is very successfully used to dam the edges of the box.

Rods are 1/2 inch diameter and are deposited using a current value of 650 amperes. Old boxes with the dovetail naturally require more material than the new boxes. Speed of the operation is such that the old boxes are built to the proper dimension in approximately one hour welding time. New boxes, requiring less metal, are built to proper liner thickness in approximately forty minutes, whereas boxes coming in for resurfacing are usually welded in twenty to thirty minutes.

The original performance expectations on this railroad have been borne out, and it is practically unknown at this time to pull a locomotive out of service between back shop operations on account of undue lateral wear or hub liner failure.

The Welding Supervisor of the West Albany Shops of the New York Central Railroad gave certain cost data before the New England Railway Club, which is repeated here.

1. Original cost per liner on dovetailed box, material off and on, old style..... $9.00
2. Original cost per liner on dovetailed box, fusion welded..... $12.00
3. Original cost per liner on new boxes, fusion welded..... $ 6.00
4. Rebuilding cost per liner on fusion welded boxes..... $ 3.50

With the old method it was necessary to drop a pair of wheels on the average of 30,000 miles. At the present time, mileages as high as 120,000 miles, or from shopping to shopping, are obtained.

When the costs are calculated over two shopping periods and proper charges made, it is found there is a saving of $47.00 per locomotive in favor of the fusion welded job.

If new boxes are used, a far greater saving is found. The value in this case is estimated at $95.20 per locomotive in favor of the fusion-welded job.

A hidden saving of considerable magnitude is also found in the fact that the locomotive can be gainfully employed, rather than having the large capital investment laying idle, awaiting driving box repairs.

While this paper deals primarily with the practices set up by the Baltimore and Ohio and the New York Central System, who are the pioneers in the practical adoption of this type of work, many railroads throughout the country have adopted this method to their requirements and it is expected that many more will follow suit.

There are many other places in locomotive repair shops where welding rods and operations of the character described can be suitably employed. The combination of the electric arc and a suitable alloy produces minimum costs and maximum operating efficiency.

Cross head shoes, shoe and wedge faces and other places may be suitably built up and repaired using this method and this metal. Prolonged performance with minimum expense should result.

The inclusion of substantial quantities of lead in arc-deposited metals forces a complete revision of our thoughts on welding technique. Further developments, now under way, indicate that practically any of the recognized bearing alloys, such as 85–5–5–5, 80–10–10, 88–10–2 and others may be suitably deposited by means of the electric arc. Such depositions result in a bearing material which is in many cases markedly superior to the standard cast form. Due to the rapid chilling effects of the electric arc, the grain structure is very fine and the lead dispersion very thorough. The lead is present in small globules and more uniformly distributed throughout the mass of the deposited metal than in the case of castings, thus resulting in better physical properties and better bearing properties.

A research and test program indicates that arc-deposited bearing bronzes possess tensile strengths as great as 50% higher than the same alloy cast or oxyacetylene deposited.

The Izod impact values, a measure of toughness and shock resistance, are better than 50% higher than cast bronze and over twice the values obtained from oxyacetylene deposits. The hardness values are likewise much higher for the arc-deposited metals and the loss of metallic constituents lower.

There appears to be much promise for arc-deposited bearing bronzes, and continued development and research will no doubt extend our present knowledge and ability.

The writer wishes to thank the New York Central Railroad Company, the Baltimore and Ohio Railroad Company, and the General Electric Company for permission to use certain data and information. Their cooperation is duly appreciated.

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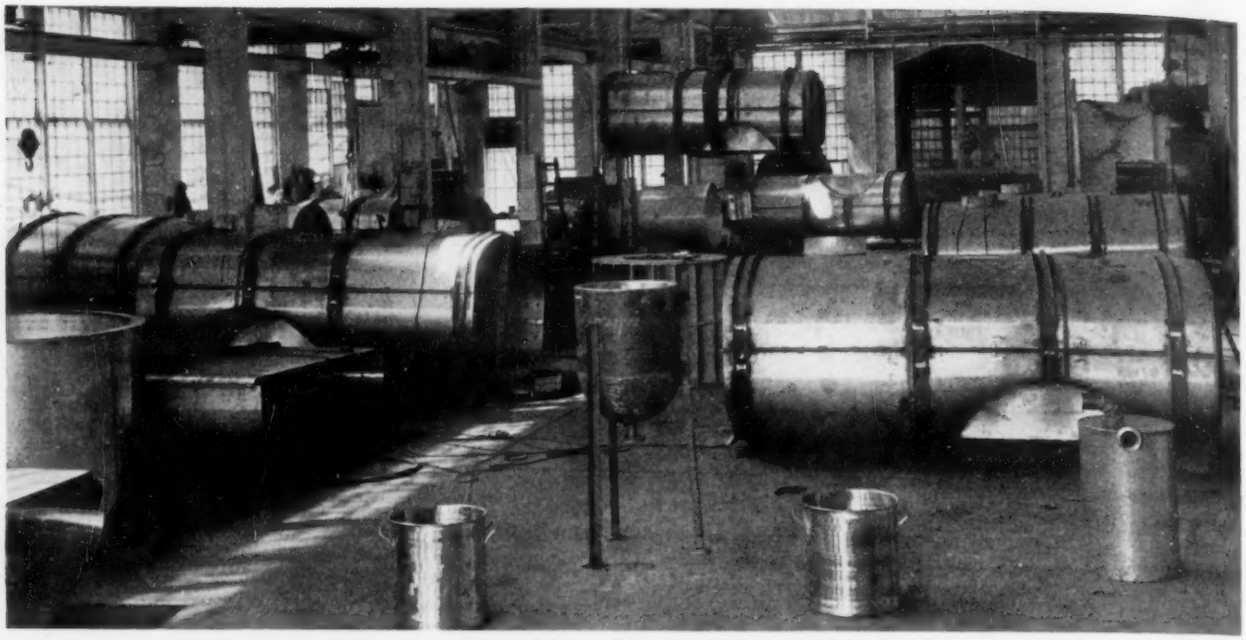


Fig. 1—General View of the Alloy Steel Welding Shops

Stainless as Applied to Pressure Vessels*

By J. C. HOLMBERG†

ALL of the stainless steels in popular usage today were practically unknown at the start of the current century and many had not even been conceived as recently as fifteen years ago. When the vast tonnage that is now used in pressure vessels in considered, this growth will be appreciated as phenomenal. Even though we have accomplished much, we are just embarking into a period that will prove to a much greater degree the usability and eventual consumption of these alloys.

The great acceptance of these materials is but a natural result of the basic law of supply and demand. For countless years industry and science have desired a material with the strength of steel and the ability to resist corrosive attack. Somewhere in the stainless groups they were able to find an alloy that would provide them with a fabricating material capable of supplying both characteristics.

Fortunately for all concerned, welding had been growing and becoming a popular means of fabricating during this same period, so that we find this method of jointure used in many installations, and were it not for this, many successful units in operation today could never have been built. Think what effect this would have had on chemical and food industries alone. In stainless and in welding, we have discovered an ideal arrangement of mutual help—stainless necessity for a satisfactory means of uniting solved only by welding—had been an important factor in the growing popularity of welding in connection with other materials; and its satisfactory performance with stainless has resulted in a broader field of absorption for these high strength, corrosion resistant alloys. The remarkable advance in the use of both welding and new alloys has not been entirely unattended with trouble and errors. Instances are known where the wrong alloy has been used resulting in unsatisfactory service—and conversely—where the right alloy has been specified but, because of a welding procedure—lacking in some fundamental—the results anticipated were not attained.

Experience and increased knowledge have done much to overcome this. Researchers have discovered the points of weakness and with the close cooperation of the various manufacturers of alloys the selection of the proper material for specific applications can be made with confidence and a great degree of certainty that the material will perform in a highly satisfactory manner.

As to the welding of these alloys—a great deal of informative data has been and is being published. The results of the experiments of the various steel companies have been made public, the papers presented at the meetings of the various technical societies are available and the excellent and instructive meetings of these Societies; notably the AMERICAN WELDING SOCIETY; have resulted in a great inter-exchange of knowledge and thus no purchaser of welded "stainless" equipment is today obliged to gamble on the outcome.

Because, as just mentioned—so much data is available for handling these new materials, it is my intention not to make any recommendations as to procedure but instead cite a few instances of various unusual pieces of equipment constructed by the company I have the honor to represent. In discussing these pieces of illustrative equipment, you will appreciate it is impossible to reveal the concern's name for whom it was constructed and that we will have to confine ourselves to a rather sketchy description of the apparatus—how it was built—unusual procedure—and its contemplated use.

* To be presented at Annual Meeting, AMERICAN WELDING SOCIETY Atlantic City, October 18–22, 1937.

† Chief Metallurgist, Struthers Wells-Titusville Corporation.

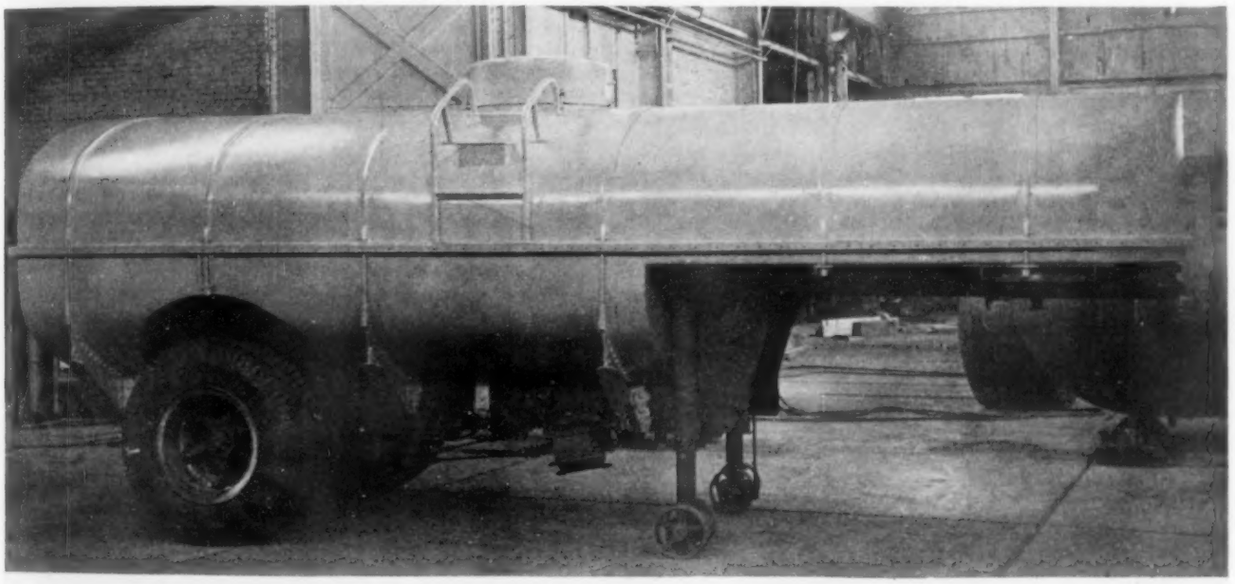
We believe our Company was one of the first to realize that an added hazard occurred when attempting to handle these newer alloys in the same shop and by the same means as heavy steel plate. For this reason a special shop was laid out and equipped for the sole purpose of working alloys.

Our *first illustration* shows a section of this shop with some partially completed vessels of various sizes and types. In the immediate foreground are several small kettles, etc., constructed of rather thin gage 18–8. In the background will be seen several peculiar shaped vessels in various stages of completion. These vessels are combination rail and truck milk tanks, built of 12 gage type No. 304 metal—then insulated and covered with 16 gage mild steel. A great deal of press work was required to form the many eccentric shapes that go to form the completed job. In welding these various shapes together it was necessary to exercise the utmost care "fitting up" the parts. An unusually large number of jigs and fixtures facilitated this operation and proved their value when polishing. These units demanded a "sanitary polished finish." To secure this, it was essential that all seams be flat with no depressions that would not polish clear and clean.

Figure 2 shows one of these vessels completed—ready for shipment. After completely welding and polishing the stainless steel interior vessel, these tanks were then completely covered with two inches of cork board insulation before the No. 16 gage mild steel jacket was applied and vessel mounted on the trailer. This was an unusual group of vessels, but I believe it is a good example of what can be done with these new steels if sufficient care be exercised.

Figure 3 illustrates six pressure vessels, 48 inches in diameter by 94 inches long. These vessels were constructed of $^{7}/_{16}$ inch thick 19–9 low-carbon material. They are used as cereal cookers by one of the prominent breakfast food manufacturers so it was very important that the interiors be polished to a sanitary finish. In fabricating, extreme care must be exerted to see that the

Fig. 2—Welded Insulated Milk Tanks



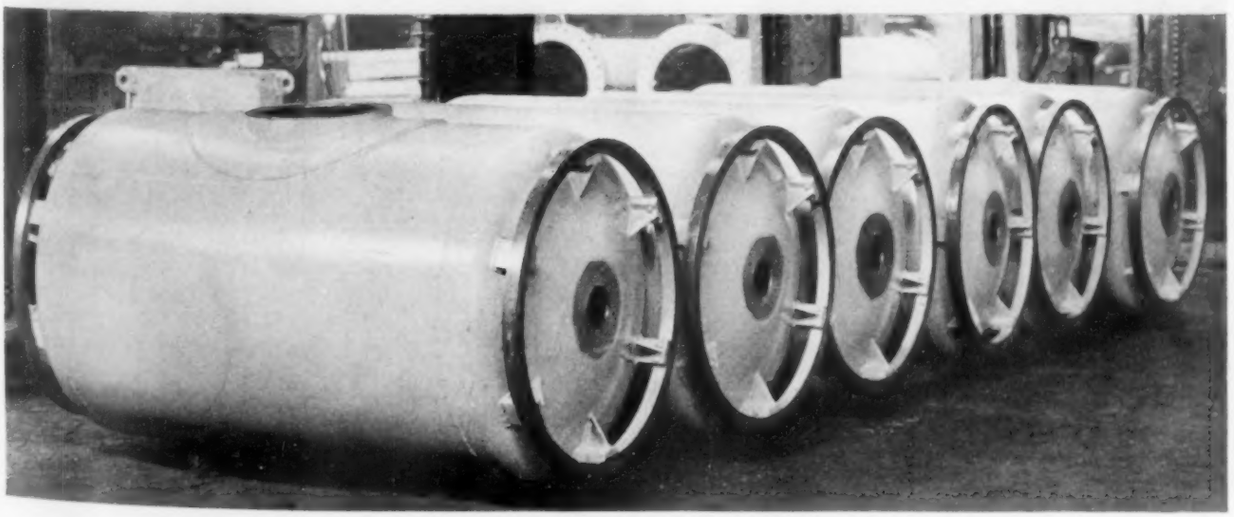


Fig. 3—Cereal Cookers Constructed of 19–9 Low-Carbon Material

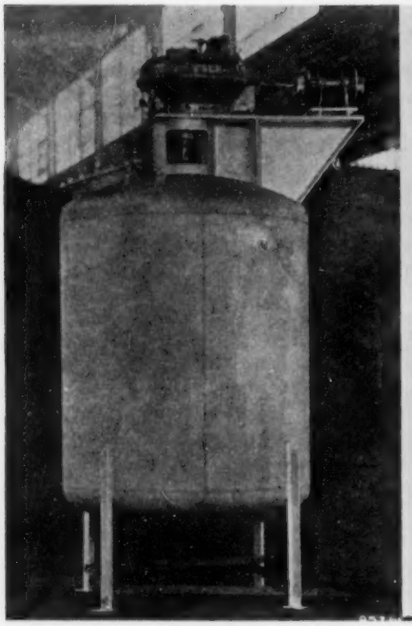


Fig. 4—18-8 Chrome Iron Mixing Vessel

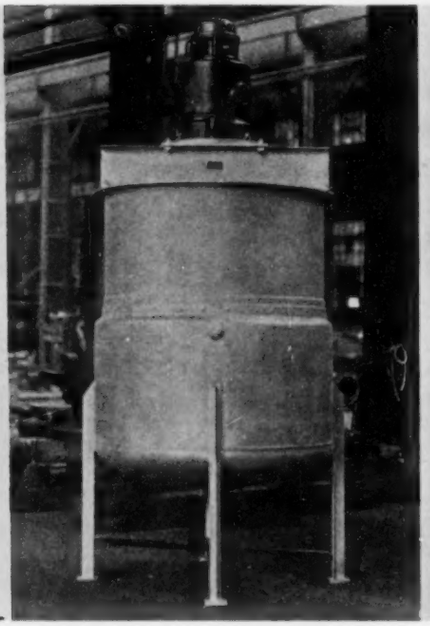


Fig. 5—Vessel Used for Mixing and Cooking

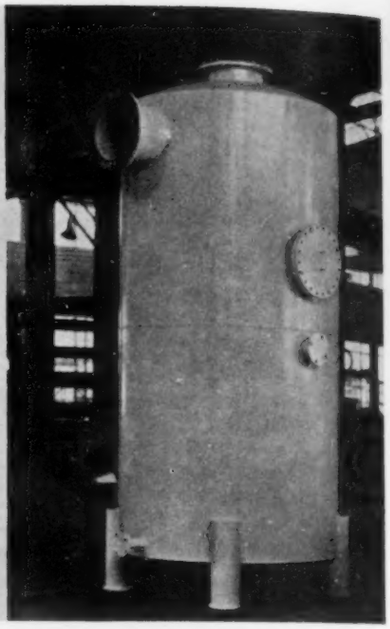


Fig. 6—Nickel-Clad Steel Vessel

abutting plate edges are in absolute alignment. If this is not done great difficulties are encountered not only in the welding operation, but also in the subsequent polishing.

Figure 4 shows a vessel of a type of which our Company manufactures a large number. These are used by several different industries and are constructed of various materials as 18–8, Chrome Iron and other compositions. This particular unit has a speed reducer mounted on the upper head, through which an agitator is driven. The agitator or propeller is so built that it must not have more than $^1/_4$ inch clearance at any point. Greater clearance would naturally reduce the efficiency.

A mixing vessel of still another type is shown in *Fig. 5*. This vessel is of jacketed construction and used both for mixing and "cooking," both operations often being performed at the same time. The vessel proper was built of 18–8 chrome nickel alloy. The jacket was of flange quality steel and attached to the main vessel by both fillet and plug welding—and this was done with electrodes of the 18–8 type. Vessels of this type cannot be given a satisfactory heat treatment after welding as the high temperature advisable for the austenitic stainless material would be so intense that the mild carbon steel would become quite plastic and not possess strength enough to retain its shape. Furthermore, the lower stress-relieving temperatures usually used for mild carbon steel would be within the critical temperature range of stainless thus producing sufficient carbide precipitation to render the stainless valueless as a corrosion resistant.

In *Fig. 6* is a photograph of a vessel constructed of 10% nickel-clad steel. It is true that this type of material is not within the exact meaning of the subject covered by this symposium, nevertheless it is included because of its increasing popularity and general interest in fabrication.

No materials have received so great an acceptance as have the nickel-clad steels where caustic service is to be endured. The nickel surface is more corrosion resistant in this particular than any of the common alloys and the steel backing provides strength and reduces the ultimate cost markedly.

The welding of this material has until rather recently been the greatest drawback to more widespread acceptance. The welds must have the strength of steel on the outside and the comparative purity of nickel on the inside. To obtain this effect, we have found it advisable to assemble and tack the various component sections to-

Fig. 7—Tower Used for Fatty Acids

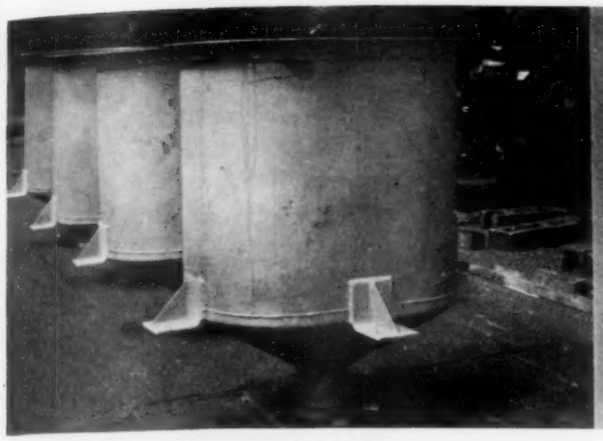


Fig. 8—Nitriding Pots Made of 18-8

Fig. 9—Welded Acetate Tanks

gether from the outer side—then weld the nickel side, using a pure nickel electrode. After completion of the nickel weld, we chip out the tacks and complete the welding from the steel side. This procedure is successful in producing joints having an iron dilution of under 5%.

In attaching the necks and other fittings much care must be used in order that no steel surfaces are left exposed. This requires that the nickel welds at these points are as a rule rather wide and should be carefully examined for evidence of porosity.

After the welding is completed, our practice has been to clean the welds thoroughly by sand blasting and then go over them with an acidified cyanide solution for evidence of iron. Any particle of iron or even a section of high iron content will produce the typical greenish blue discoloration of ferri-cyanide.

Columns of various sizes and types are becoming common sights not only around refineries but also at plants in chemical and allied industries. The uses to which these might be put are as varied as the materials of which they are made.

Figure 7 illustrates a "tower" 20 feet in height built for use with Fatty Acids at 500 lb. pressure and 800° F. The specified materials was one of the newer alloys that is becoming popular, namely 19-9 with columbium added as a stabilizing element. The plate's thickness was $^3/_4$ inch which is rather heavy for material that is as expensive as stainless. However, the service, temperature and pressure rendered it necessary to fabricate of this material. Perhaps the most difficult operation in building this structure was that of forming. These austenitic alloys cold work very much and, as a natural result, great pressure, as well as skill, is needed to form and roll the sections.

Four nitrating pots are shown in *Figure 8*. Some of these vessels were formed of $^1/_4$ inch thick 18-8 chrome nickel material and, after welding, were given a 2000° F. anneal followed with a water spray to quench, maintaining complete solution of the carbides.

One other alloy is also used for these nitrating pots. This material, commonly known as Chrome Iron, usually containing 15 to 16 per cent chromium was long considered non-weldable because of the tremendous grain growth and resultant brittleness of the weld. This difficulty is now largely of the past due to the untiring efforts of many investigators who have been able to demonstrate that this alloy—if intelligently and properly handled—is one of the finest materials in the stainless group. It is my belief that no other one is as good for nitric acid service.

Our practice in handling chrome iron has been to carefully determine the analysis first—that is, of the plate material and after this is done the electrodes are selected that will produce a weld most closely approximating it in analysis. In welding this material about one and one quarter per cent of chromium is oxidized in passing through the arc so it is most important that the respective analyses be known.

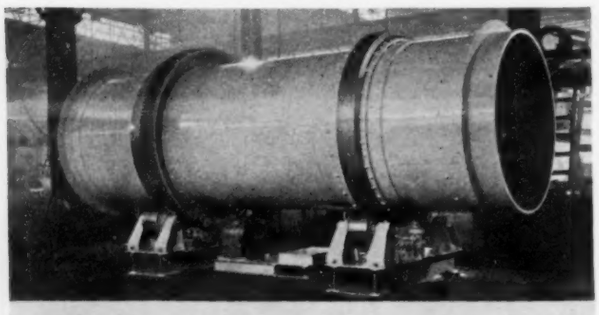
Our Company has found it advisable to slightly preheat all the straight Chrome Irons before welding. This minimizes the shock to which the plates are subjected when the arc is started.

Probably the most important operation in connection with fabricating these alloys after the welding operation is heat treatment. This differs from that given 18-8 (which is largely for the purpose of enhancing the corrosion resisting properties) in that with the Chrome Irons it is distinctly a process for the express purpose of minimizing the brittleness caused by excessive grain growth in the welded areas.

Our experience has been that to secure this increase in ductility—a spheroidizing treatment is the most effective. Five years ago we went into this matter quite thoroughly and evolved a heat treatment basically the same as is used for the spheroidization of the high carbon and S. A. E. grades of steel and, as a result, we have been

Fig. 10—Jacketed Condensed Soup Vessel

Fig. 11—Chrome-Nickel Molybdenum Dryer



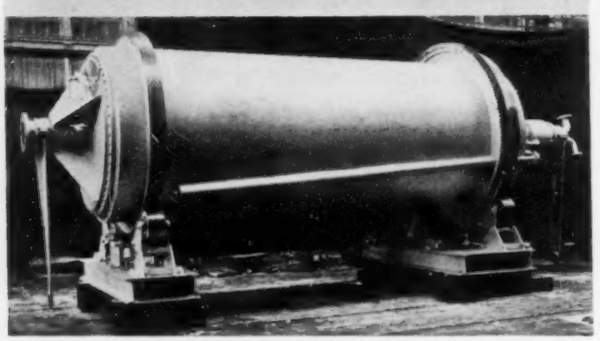


Fig. 12—Rotary Vacuum Dryer

able to consistently produce welded structures of Chrome Iron material having corrosion resistance equal to the virgin plate and at the same time are able to guarantee bend tests of 180° with radius equal to the plate thickness. We have not as yet been able to raise the impact values as high as we would like, but nevertheless they are sufficient for service requirements and will run rather consistently around 10 to 12 foot pounds Charpy.

The heat treatment we use is to heat slowly to a temperature of 1475 to 1575° F. maintaining at this temperature for six hours. The exact temperature is dependent upon the chromium content as this governs the critical point at which spheroidization occurs. We then cool very slowly to about 1100° F. and then either air or furnace cool at a normal rate. Many metallurgists recommend a rapid cool from the 1100° temperature but our records do not show that this particularly affects the results on welded vessels.

The synthetic thread industry is a large consumer of many different kinds of stainless. *Figure 9* shows part of an order we constructed for a manufacturer in the East. These are known as Acetate tanks and are 46 inches in diameter by 80 inches high and were designed and built for 150 pounds pressure. The construction of these is unusual in that both heads are of conical shape and pressed to this shape and formed without a seam. Most people familiar with pressing operations will agree that this is a difficult shape to form without reducing the gage of the material in the center to a great degree.

A jacketed vessel, one of many, the products of which we have all probably consumed, is shown in *Fig. 10*. This kettle, 65 inches in diameter and 60 inches deep, was built of Type 304 stainless and was polished to a high finish both in and outside. These are used by a manufacturer of condensed soup in the preparation of his product and, because of the service, it is doubtful if any stainless vessels are built having any finer finish. The bottoms of both the vessel and its jacket were formed of "orange peel" sections which produced a true hemisphere making both cleaning and draining a simple operation.

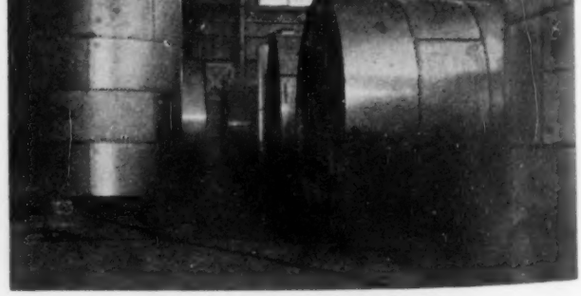
Many products require drying before they can be marketed. This is done in units, the many various types of which are not only numerous but often complex. In *Fig. 11* is shown one of the more simple horizontal type dryers constructed of Chrome Nickel Molybdenum alloy—and was furnished complete as shown with steel tires, rollers, ring gear, etc. This photograph does not show the interior vanes, and other component parts which cause the contents to tumble and prevent caking. This particular unit is in use in one of the plants of one of the largest Chemical Companies but we are not aware of just what product it is being used for.

Probably one of the most complicated and intricate structures ever built in this country is that shown in *Fig. 12*. This apparatus, known as a rotary vacuum dryer, was 65 inches in diameter and 16 feet long and the plate thickness was $^{9}/_{16}$ inch. This dryer was fitted with internal scrapers and grinding rolls, all of which had to be very closely fitted to the shell. These internal parts do not revolve with the shell but remain stationary. This design was developed only after a great deal of minute and detailed engineering had been accomplished. The vessel is used to evaporate a mixture of milk and sugar and 18–8 was the material selected for fabrication.

Figure 13 shows the only stainless steel vulcanizer that we have knowledge of ever having been built in this country. It was constructed of $^{1}/_{2}$ inch thick 18–8 chrome nickel alloy and was 50 inches in diameter by 18 feet long. It is used by one of the large manufacturers of motor cars for the treatment of steering wheels. The use of stainless in this instance was justified by the fact that particles of rust would drop off of mild steel and spot the steering wheels which would detract from their appearance. This apparatus when built of mild steel would have a value of about $2000 but when the stainless was used the value became $10,000. This is mentioned to show to what lengths the motor industry will go to increase the appearance and value of their products.

Several Acetic acid storage tanks are shown in *Fig. 14*. These tanks, 12 feet in diameter by 15 feet, six inches high were built of 12 gage 18–8 material. The size and

Fig. 13—Stainless Steel Vulcanizer



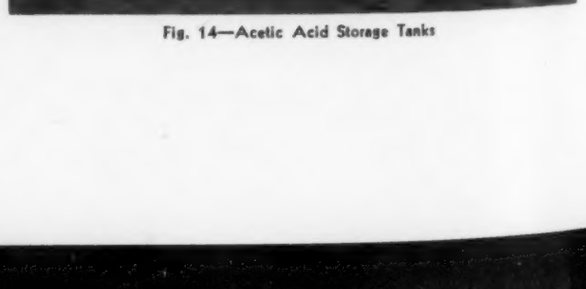


Fig. 14—Acetic Acid Storage Tanks

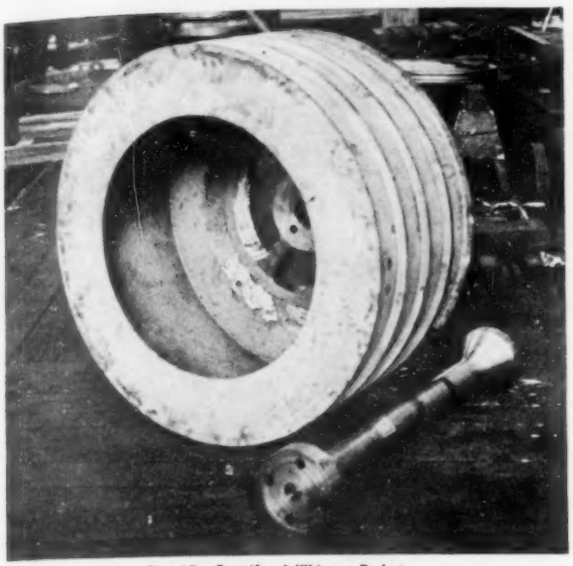


Fig. 15—Centrifugal Wringer Basket

thickness of the plate in these tanks was such that annealing or heat treatment after welding would be impracticable so that it was necessary to develop a method of welding that would eliminate, or at least minimize, carbide precipitation. This process, on which we have made patent application, is what we term our *Water-Cooled Welding Process*. In this method of welding a jet of cold water is played on the underside of the weld as the operator progresses along the joint. This causes practically instantaneous cooling of the deposited metal and the plate material immediately adjacent. The austenitic stainless steels are chosen by many industries because of their value as a corrosion resistant medium, but if this valuable property is lost or reduced because of carbide precipitation, in the welded areas, then the material itself becomes unsatisfactory. It was this condition that prompted us to develop this technique, because often structures are so designed that either because of size or shape, heat treatment after fabrication is worthless. Since we first used this process we have successfully applied it to a large number of vessels and have found it to be entirely satisfactory, particularly on thin sections.

Figure 15 is a centrifugal wringer basket and spindle. These are built of various materials, dependent upon the service to which they are applied. The basket is formed of a perforated sheet having one longitudinal seam—the supporting member is a stainless steel casting and mounted on the bottom head by means of either riveting or welding. After fabrication of these it is necessary to dynamically balance them because of the very high speeds at which they revolve. To facilitate this balancing, much care is mandatory to prevent sections or welding from lack of uniformity.

One of the most interesting pieces of equipment and unusual uses to which stainless has been applied is shown in *Fig. 16*. This piece of equipment is an X-ray machine designed for the treatment of cancer and was built for Columbia University—Crocker Cancer Research Department, and is now in operation in the Presbyterian Hospital in New York City. This unusual appearing vessel was built of type No. 306 stainless steel and is 4 feet high by 42 inches in diameter and the extending arm is 5 feet long. The plate thickness is $^1/_2$ inch with 2-inch heads. Stainless was selected as the fabricating material because of its greater density which was important owing to the tremendous vacuum that is necessary for successful operation. The extending arm is used to exhaust all the air ordinarily considered possible after which the highly efficient oil pumps in the nozzle protruding from this arm are started and what little air might remain is thus extracted. A one-inch copper coil is an integral part of the apparatus and in operation this carries the cooling water. The X-ray tube operates at one million volts and is probably the most powerful machine of this kind in existence. The entire equipment is sheathed in four inches of lead to stop any stray dangerous ray radiation. When treatments are being given (through the nozzles protruding from the sides) the patients are usually protected by a sheet of lead $^1/_2$ inch thick. This is necessary to reduce the power of the machine for ordinary applications.

The widespread adoption of these stainless alloys has been progressing at a pronounced speed for the past few years, but even so, we have every reason to believe that even a more widespread use will be made of them in times to come.

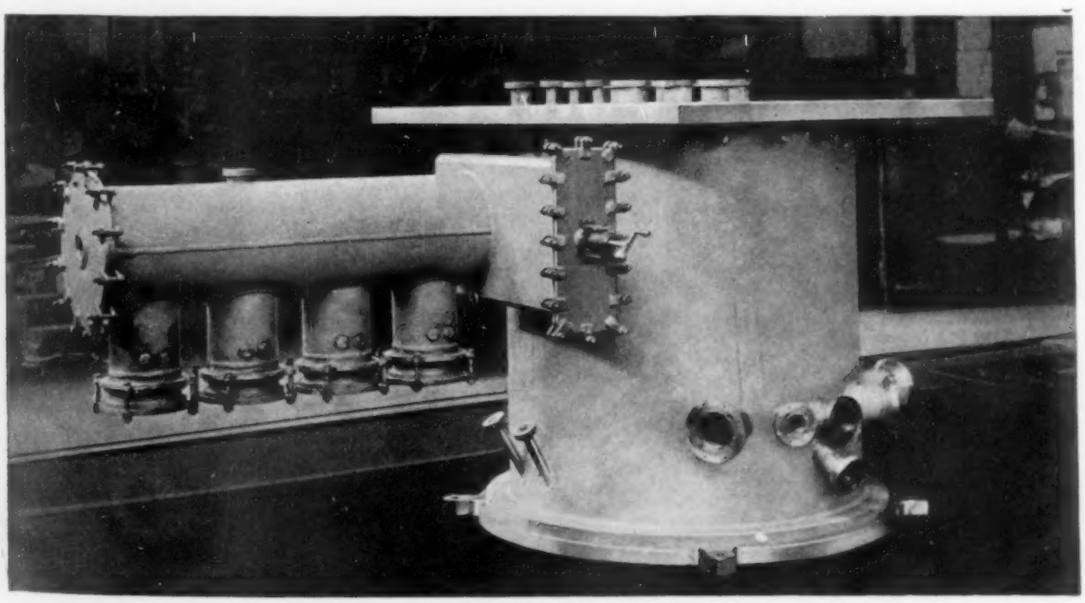
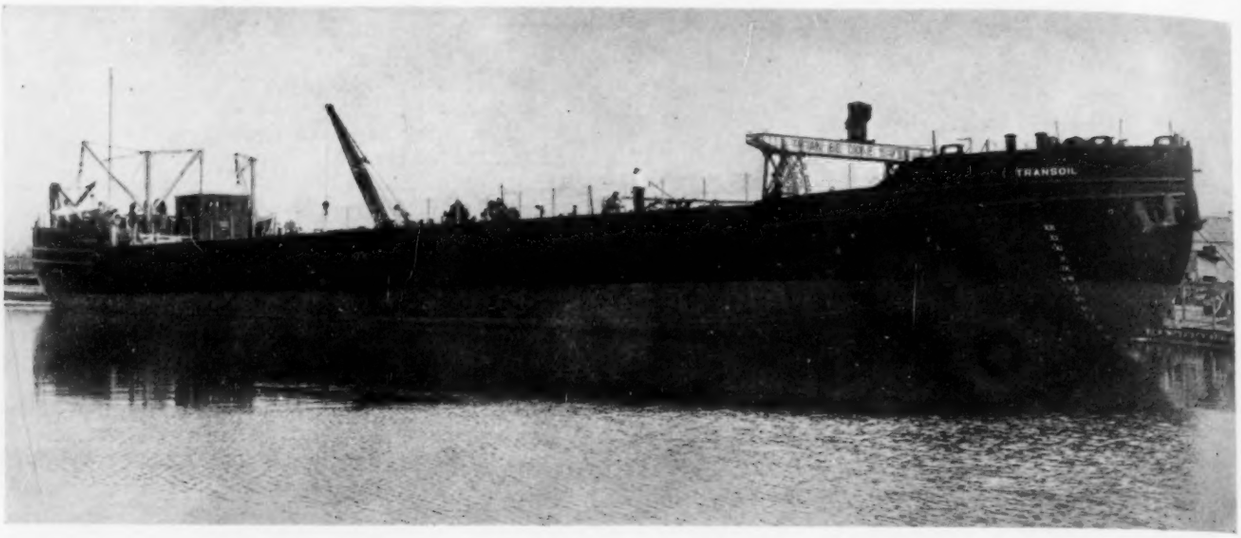


Fig. 16—Equipment for X-ray Apparatus Constructed of Stainless Steel



M. S. Transoil, 258-Ft. Welded Tanker

All-Welded Steel Tankers*

By A. C. LEIGH†

"THE Use of Electric Arc Welding" by the ship-building industry started about twenty years ago, first being used as a war emergency, or I might say "misused," as the failures due to unskilled welders and improper equipment gave welded construction a serious setback, and did much to retard the natural advancement of the art. In spite of these failures welding offered the solution of so many problems that it could not be ignored, so the pioneers with a reputation to make, rather than one to lose, took it upon themselves to perfect the art.

The forerunner of the "All-Welded Steel Tanker," no doubt, was the welded oil storage tank. It was a natural development that the welded joint should first be substituted for the riveted joint in tank construction and more especially in oil tanks where tightness is paramount and where riveting in its highest developed form often failed to give satisfactory and lasting results. The next logical step in this field was the all-welded construction of the water-borne tank, the oil barge or tanker. The oil barge or tanker is a composite union of a series of tanks.

In 1934, only three years ago, Mr. David Arnott, Chief Surveyor of the American Bureau of Shipping, gathered together comprehensive data on various welded barges and read before "The Society of Naval Architects and Marine Engineers" a paper entitled "Some Examples of Arc Welded Ship Construction." The paper was very interesting, due to its wide scope, some twenty vessels being described, which represented the outstanding achievement of numerous building yards. The usual articles, previous to this, had been written around an individual piece of equipment produced by a certain organization. The discussions of this paper after its reading did much to enhance its value. Mr. John W. Hudson, in his discussion stated: "Mr. Arnott's paper shows plainly the scrambled state ship welding is in at present." Remember the date—1934—three years ago. This indicates that in spite of the many outstanding achievements accomplished in fabrication by use of welding in the marine field, we have much unconquered ground remaining. By this I refer to the solution of the practical problems, for today, as it should be, the scientific progress is in advance of the actual practical use. In other words, welding, as applied to ship-building, could be likened unto the college graduate who is "chuck full of theories but no place to go."

The "All-Welded" tanker, as is customary on other projects of this nature, receives its initial start in design. The first welded tankers followed designs which had been developed for riveted craft, simply substituting welding for riveting. We then reached the period of rivet-welded construction, thence to the small completely all-welded steel vessels, principally barges. From all of this experience, we arrived at the point where the all-welded steel tanker has been produced and a few have been built which are in service and performing satisfactorily in every way. These all-welded steel tankers have proved so successful that their owners will probably never again build of riveted construction.

It is generally recognized that good welding is infinitely better than riveting and that the average welded joint is stronger than the parent metal, whereas the best riveted joint fails to develop a joint equal to the strength of the metals joined.

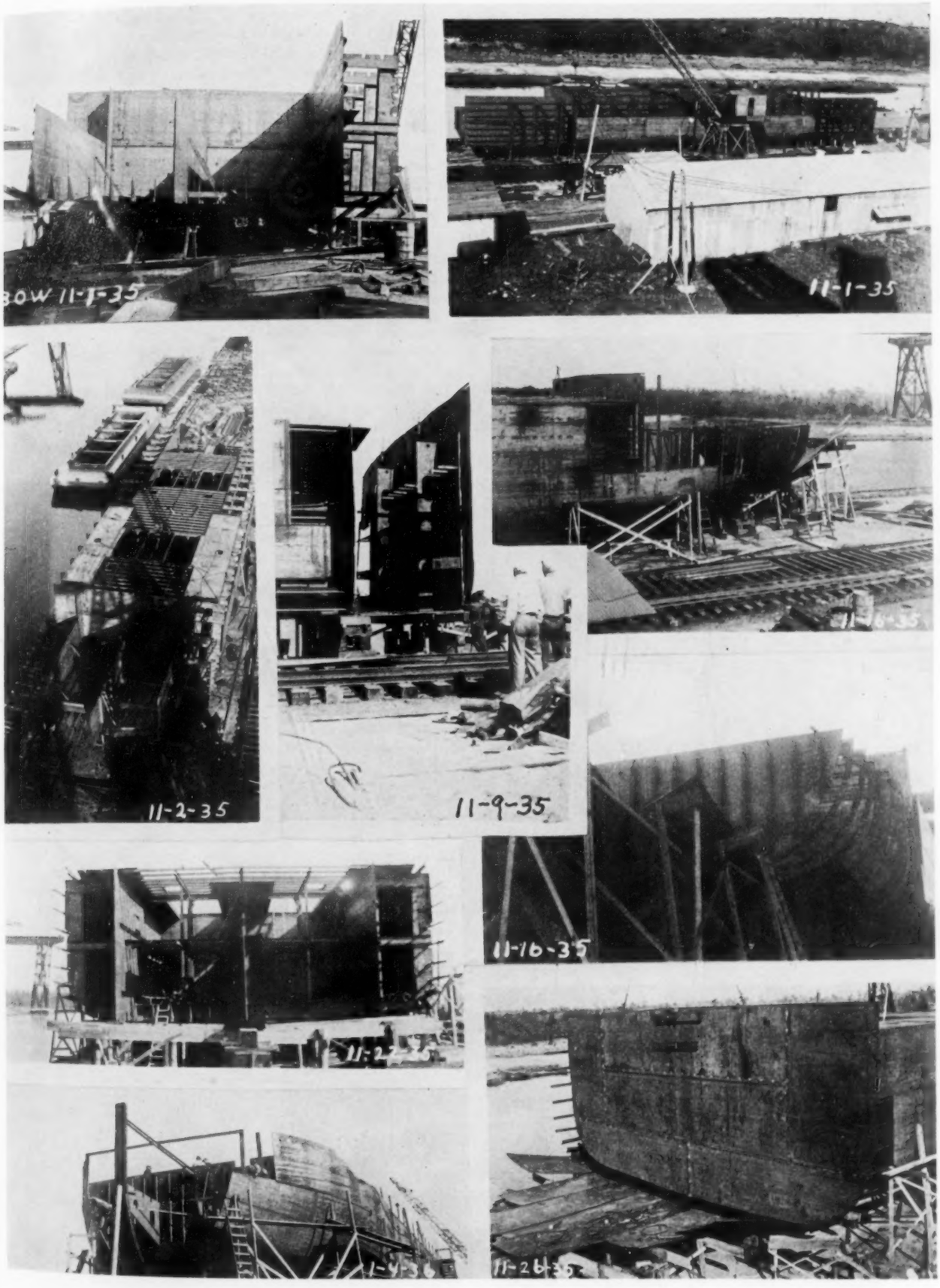
It is not uncommon for the present day specifications to state: "Welding is to be performed in a manner which will avoid buckling of plates and which will avoid undue stresses in materials."

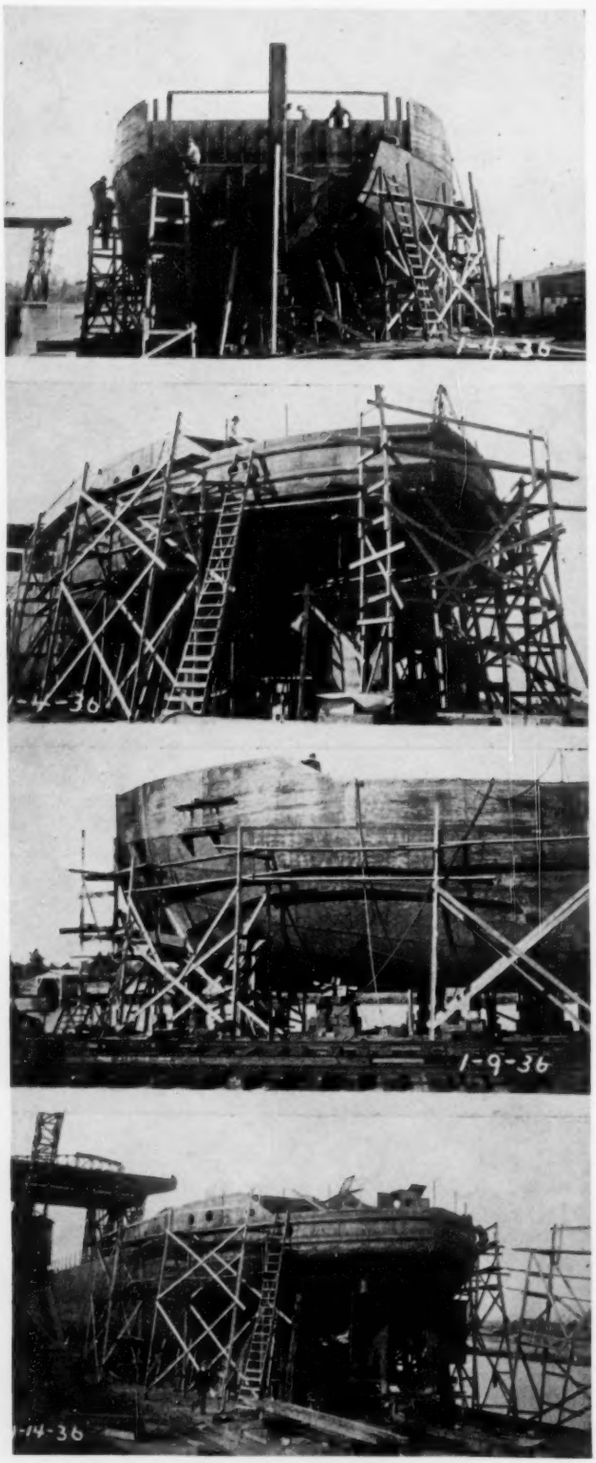
It is my contention that it is in the design where these difficulties must be controlled. A proper design will permit correct welding procedure, resulting in a completed unit practically free from distortion and buckled plates or locked-in stresses. A poor design cannot always be corrected in fabrication. Today the designer is lim-

* To be presented at Annual Meeting, AMERICAN WELDING SOCIETY, Atlantic City, N. J., Oct. 18-22, 1937.

† Marine Engineer, The Ingalls Iron Works Company.

Pictorial Views in the Building of All-Welded Tankers—Notice Dates on Each Photograph





The Tanker Nears Completion

ited somewhat, due to the lack of proper rolled sections for use in building up the all-welded unit, and until someone takes the initiative and calls together the Naval Architects and builders to develop standard sections for welded construction, and interests the mills in producing them, we will not reach our fullest possibilities in all-welded ships or tankers.

The independent designer also faces the problem of developing a design upon which correlative competitive prices can be had. Each builder has developed his own method of fabrication involving certain processes of assembly in which he may employ automatic welding devices of his own invention; therefore, at present it is quite customary for those seeking competitive prices to allow the various builders to make changes in the design which will permit him to make the best use of his methods and fabrication facilities. At some future date we, no doubt, will have perfected machinery of various types of automatic welding which will permit universal standards. Then we will have arrived at a point where the methods and machinery of the various builders will be more or less standard for all-welded construction.

After the design, the next important step in construction of an all-welded tanker is the preparation of the detail plans. Quoting from today's specifications, "the assembling of all joints shall be such as to permit good welding." This covers a vast field and here again, the answer to this problem should be given in the design. The draftsman preparing the various detail drawings should not be called upon to assume the responsibilities of the designer. In many cases he is inexperienced in the application of the welding deposit and through this lack of knowledge his drawings do not permit the assembler and welders to take the fullest advantage to obtain the easiest welding. The experienced designer, who visualizes all the necessary steps which must be gone through in the fabrication of the tanker, can so design the various units that the detail plans can be made by the more or less inexperienced draftsman.

Following the detail drawings is the fabrication of the actual boat. The word "fabrication" as applied to the ship-building industry, I believe, made its appearance about the same time that welded construction was first used. This was in 1917 when, as a war emergency, the work of punching and shaping of plates and to some extent assembling and riveting together of sections were done in structural and plate steel fabricating shops throughout the country whose ordinary duties were the fabrication of bridge and tank work. This pre-fabricated work was then sent to the shipyard where the actual ship was built. Today we find that the terms fabrication and welded construction are both definitely entrenched in our ship-building industry. The majority of ship-building firms who are using welding as a method of construction are pre-fabricating various sections of the ship in sections which are limited in size only to those which can be successfully handled in assembly or erection. This is so that full use can be had of automatic welding machinery and to obtain the greatest amount of welding which may be done in a down-hand position. The theory advanced by some of our authorities on welded construction is that as much of the ship as possible should be pre-fabricated under cover because the temperatures may be better controlled. I do not agree with this entirely. It is an excellent thing to have protection for the workmen from the weather, also having the work under cover expedites the work as there is no loss of time due to adverse weather conditions. Also, there is unquestionably an advantage to be able to control the positions in which the welding is applied. I recall some twelve years ago the Westinghouse Company in Pittsburgh, in order to advance welding in the building industry, took it upon themselves to erect an entirely welded building. The various engineers in the Pittsburgh District were invited to the building site to actually view the work. The temperature at that time was hovering around zero and I asked the Chief Welding Engineer of the Westinghouse Company his opinion regarding depositing welding during zero weather. He informed me that the difference between zero and our normal summer temperature was

only some 80 degrees. The temperature at which welding is deposited is approximately 6500 degrees. He therefore stated that it made no difference whether welding was deposited in summer temperatures or at zero temperature.

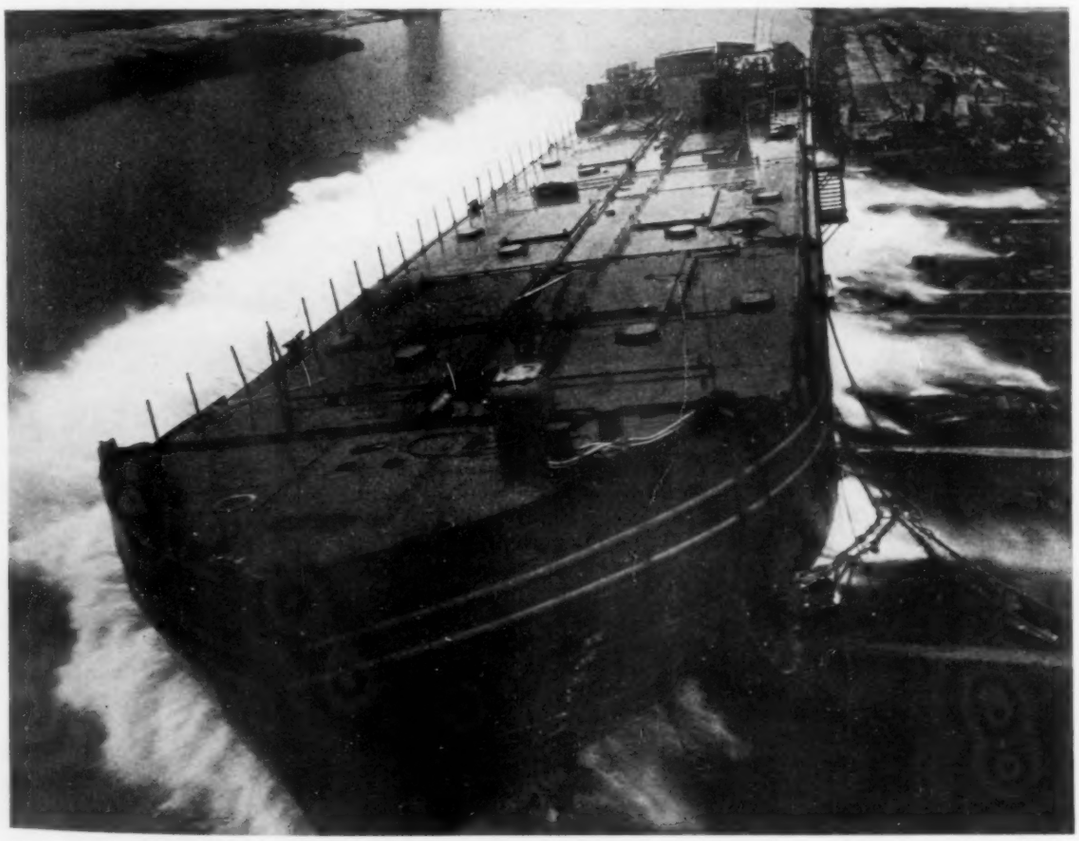
Early last year our organization, The Ingalls Iron Works Company, having successfully produced approximately 200 tank barges, ranging in size from 4000 barrels to 14,000 barrels, was called upon accept the responsibility of building an all-welded tanker. This tanker, the MS "TRANSOIL," at that time, was reported to be the largest all-welded tanker afloat. She was built to the following dimensions:

Length between perpendiculars	251 Ft. 3 Inches
Length overall	253 Ft. 0 Inch
Breadth, molded	43 Ft. 0 Inch
Depth, molded	16 Ft. 8 Inches
Gross Tonnage	1600 Tons.
Capacity	20,000 Bbls.

Until the building of the "TRANSOIL," the majority of tankers built in this country, wherein welding was used, confined the welding construction to the parallel midship body. The molded forward and after ends were constructed by the conventional riveted method. The reason for this was due to the fact it had been proved that the parallel midship body could be welded at an equal cost to riveting or somewhat cheaper. Lieutenant R. M. Watts, Jr. in his discussion of Mr. Arnott's paper states that at the New York Navy Yard where they were building a 110-ft. all-welded sea plane wrecking derrick they were able to effect a considerable saving by welding over the riveting on the flat bulkheads and flat bottom structure; however, this savings and more too was dissipated in the curved portion at the bow and stern and around the propeller shaft tunnels. He agrees with Mr. Arnott that this was due to the greater difficulties in erection and the necessity for an almost perfect fit in a curved surface which did not have the rivet holes for the pulling up of material with heavy bolts and which did not have the broad faying flanges of angle bars from which a skillful fitter could steal $^1/_8$ to $^1/_4$ inch in regulating. The plates for the hull of the "TRANSOIL" were not formed by firing. Templets were made and the plates were formed cold in a press by a bumping process, in less time and at less expense than the conventional method of heating, hammering and pressing.

What is termed the lines of the boat can best be explained to the laymen as the lines showing the form of the boat. These are laid down on the mold loft floor in their various projections and from them the mold loftsmen make templets which are used as a guide for forming the plates to the proper curvature.

For riveted construction, it is usually customary to erect the internal framing of molded ends and the plates are then fitted to this skeleton. It is often necessary in fitting the plates to more or less "cut and try" during construction; that is, to place the plate in its proper position and if it is not properly formed to fit to remove same and make the necessary adjustments. It is evident that this system could not be worked on a welded construction because of no holes in either the plates or frames for drawing them up to their proper position and in the majority of cases the sections used in the frame have no flanges to assist in this operation. On the "TRANSOIL" we timidly approached this situation as this was our first attempt at welding molded work. Advice was sought from various sources but we quickly learned that no generally successful economical method had yet been devised. During this investigation, we did find, how-



The Launching

ever, that a method employed in one of the yards in Germany was to erect a steel cradle, this cradle being very similar to a skeleton female die shaped to the external form of the tanker into which the shell plating was lowered and tack welded into position. The internal framing was then erected to fit the form thus obtained. It is very easy to see that this method would result in exhorbitant erection costs, so after careful study, we decided that we would erect these ends very similar to the method now employed in the erection of cantilever bridges—that of erecting the various portions of the framing and plating by progressive steps. This method was found to be very successful and while naturally our costs for this particular work were higher than the welding work on the straight midship body, they were not excessive. The experience thus gained in constructing these molded ends indicates to me that considerable of the difficulties which are encountered in the welded construction of the molded ends of ships can be overcome if the design is so made that erection can be done in a similar manner to that which we employed. It was noted in welding the plating of these molded ends that as expected there was considerable shrinkage developed in the plating. The results of this shrinkage were indicated in the bulkheads and in the deck plating which, being fore shortened, naturally buckled. This buckling and distortion was not caused directly by the welding deposit and therefore, of course, was not alarming. This can very easily be overcome by running the strakes of plating vertically on the bulkheads, spot welding the joints for erection and after the shell plating has been welded, the spot welding can be chipped off, thus allowing the bulkhead to shorten to the necessary width. This difference in width for the deck plating can be taken up at the seams in a similar manner; thus, here again, we find that the proper design can control the condition.

There were over 25 miles of lineal footage of welding used in the construction of the "TRANSOIL." All welding was done with heavily coated electrodes, $^3/_{16}$-inch rods for all of the vertical and overhead welds, $^1/_4$-inch rods for down-hand welding and $^1/_8$-inch rods for the welding of the thinner plates of the superstructure. Current was supplied by direct current, reversed polarity arc-welding machines at from 30–50 volts and 125–300 amperes.

By means of a transit, bench marks on the ways, etc. a careful check was kept during erection for indications of shrinkage. It was expected that shrinkage would be noticed in the four principal directions:

(1) Loss of length
(2) Lifting of ends
(3) Loss of beam
(4) Possibility of the boat being out of line.

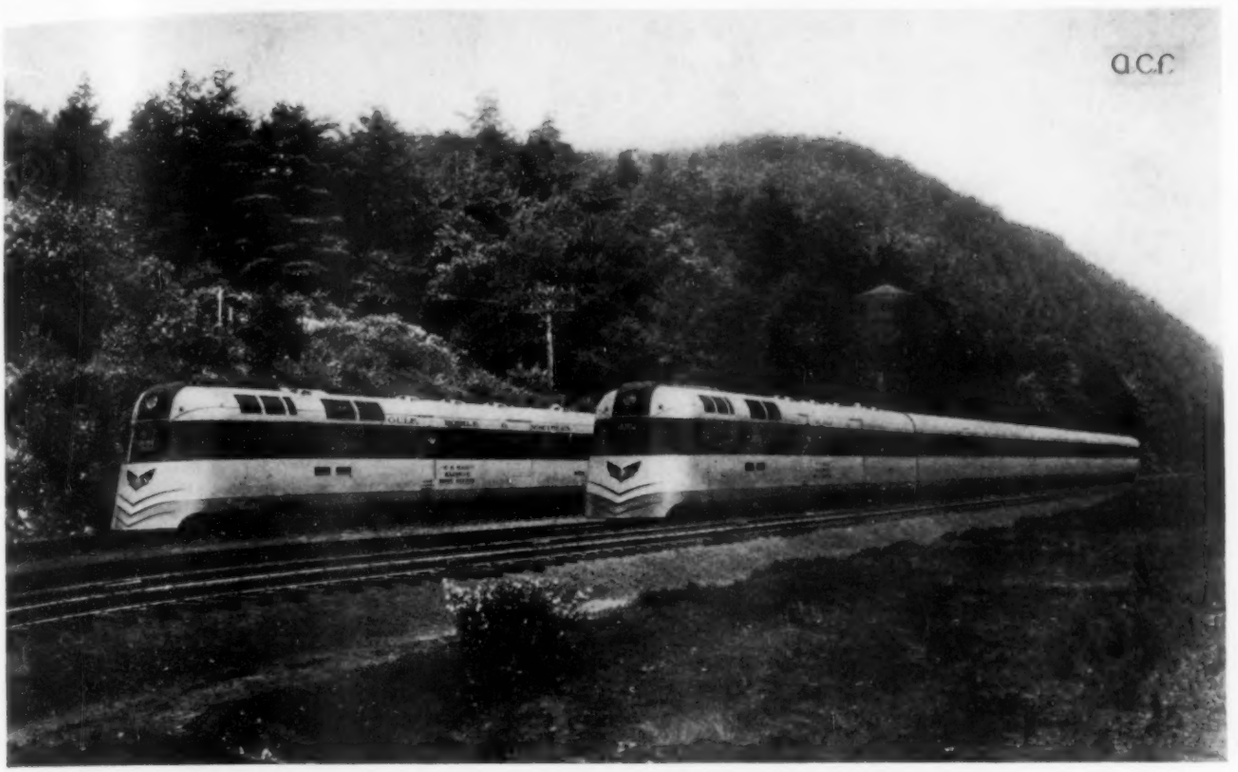
On the best available information, it was calculated that there would be a shrinkage of approximately 3 inches in length. Actually, just previous to launching, we measured the shrinkage for the full length of 258 ft. and found it to be $1^3/_8$ inches. Of this, 1 inch was in the parallel midship body. The shrinkage in the full breadth of 43 ft. ran from $^1/_4$ inch to $^3/_8$ inch. The bow was about $^1/_4$ inch too high and the stern about $^5/_8$ inch. Due to the careful check which we maintained while constructing the boat, we discovered shortly after starting welding on the bow that it was out of line about $^1/_2$ inch to the starboard. Due to this, the welding deposits were concentrated on the port side with the result that the bow of the vessel returned to its proper position.

It was interesting to note also during the welding of the bow when the welding of the lower part of the fore shell plating had progressed to some extent that the bow was about $^1/_2$ inch high; however, when the welding was completed on the deck and internal framing, the final check indicated the bow to be about $^1/_4$ inch high.

An incident occurred during the welding of the stern tubes which indicates the necessity of careful supervision of welders at all times. The welding of the stern tubes required heavy continuous welds to the shell floors and bulkheads and the concentrated heat of continuously applied welding would naturally throw the tubes out of line. The day welding crew, following a carefully planned procedure, welded the starboard tube in position without difficulty. The night crew, misunderstanding the instructions, followed their own method with the result that the port tube was drawn out of line $^1/_2$ inch.

Much care was exercised in using the proper electrode for the various conditions of welding. I do not now have reference to the size of the electrode, but to its welding characteristics. Much improvement continues to be made in the quality of electrodes and especially with respect to the ductility of the deposited metal and their action on the fused part of the parent metal and the speed of the welder. It has been our experience that even on straight-a-way flat welding we can obtain greater speed by hand, and equally as good welding, as with the automatic machines. Of course, the skill of the welder is an all important factor. However, with the great improvement in electrodes and welding machines, plus proper instructions to beginners and periodical tests by the American Bureau of Shipping, our men either soon become proficient or their services discontinued. Great numbers of good welders are being made right along and this is important to the art because scarcity of welders would make costs excessive and retard progress. Our men are worked on the berth system at a basic hourly rate with a bonus for quantity and quality in excess of our standards. When a man cannot make more than his basic rate his services are not satisfactory.

Much has been written concerning methods of welding in order to eliminate distortion and locked-up stresses. Mr. Wilson, Assistant Surveyor of the American Bureau of Shipping, sums this up in a joking way by stating that the best welding procedure to follow is to weld promiscuously. I agree that it is necessary that a carefully planned procedure of welding must be followed in order to obtain the correct results, that the designer must have this in mind as it is a design problem. A poor design cannot be corrected in fabrication. I agree with a long list of Naval Architects, Marine Engineers and owners who are of the opinion that welded ship construction will eventually entirely replace riveted construction.



The Two "Rebel" Trains Built for Gulf, Mobile and Northern. The Smooth Exterior Is Made Possible by the Use of Welded Construction

Welding of Railroad Rolling Stock*

By V. R. WILLOUGHBY†

IN 1927 it was my privilege to prepare for presentation at your Fall meeting, a short paper on, The Use of Welding in Car Construction.

In the present paper I wish to bring the record of welding in car construction up to date.

The last ten years have been ones of great progress in railway car design, and welding has played an important part.

The author is not a welding expert, simply a car designing engineer. He desires to be excused from discussing the purely technical phases of welding. As a user of welding in his designs he approaches the subject from a car engineer's view-point.

The fusion weld has become a well known factor, practically as much so as the rivet. Suitable welding rods, correctly adjusted current, used by certified welders have removed a goodly percentage of the previous doubt. We designing engineers now have another efficient means for joining structure members together. In many places this is our most efficient method. The railroad rolling stock fraternity, pressed for lighter and stronger equipment, has not been slow in utilizing the present-day fusion weld.

Up to 1927 the use of welding in new car equipment was, except in very isolated cases, only incidental. What has happened in the last ten years?

Freight Cars

Let us first consider the freight car:

In 1930 the Baltimore and Ohio Railroad built at its Mt. Clare Shops, Baltimore, Md., a 95-ton all-welded steel hopper car. This car has been in the Baltimore and Ohio coal service since that time and periodical inspections have fully justified the confidence of the designers in a welded car.

In 1931 Pullman Car and Manufacturing Co. designed and built five all-welded 70-ton hopper cars for the Chicago Great Western Railroad. The light weight of this car was 45,900 lb. Compared with 50,200 lb. the weight of probably one of the lightest riveted designs of 70-ton cars, there is obtained a weight saving of 4300 lb. Inasmuch as the hopper car is generally loaded to its full rail capacity, this welded car can carry 164,100 lb. of pay load, whereas the riveted car referred to can carry only 159,800 lb. This means that for each trip the welded car can carry 4300 lb. more pay load than the riveted car, or almost 2.7% more and without any additional transportation cost. This car had many unique features of construction such as gas welding for assembling the heavy frame parts and electric arc welding for the thinner members.

In 1931 A. C. F. built for the Chesapeake & Ohio Railroad five 50-ton gondola cars. These cars were equipped with a one-piece cast steel underframe. The floors and superstructure were of welded construction. Later in the same year they built a similar car but with a

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* To be presented at Annual Meeting, AMERICAN WELDING SOCIETY, Atlantic City, October 18–22, 1937.

† General Mechanical Engineer, American Car & Foundry Co.

rolled steel riveted underframe, the floor and superstructure being assembled by welding. These cars were placed in heavy service, were carefully watched and the latest reports are very favorable toward welding. In these cars all welding utilized the electric arc.

In 1931 the American Railway Car Institute, in conjunction with the Car Construction Committee of the Association of American Railroads, was requested to design a standard box car using open-hearth steel with riveted construction. Reasonably light weight was desirable.

In approaching this design one of the first things the builders' engineers considered was the center sill construction. Two rolled structural members tied together at their tops by a cover plate, riveted in place was the prevailing practice. The center sill is the backbone of the car underframe and must resist all buffing shocks as well as other stresses imposed upon it by the lading.

The car builders' engineers felt that a sill rolled in one piece would make a better construction than one built up of three pieces. The rolling of a unit sill, however, was not at all practical. By welding together two specially designed Z-sections, along the top center line, a one piece sill construction was formed, attaining the practical advantages of a unit-rolled sill.

Due to changes in dimensions in the sill construction this new construction resulted in a better sill. Eccentric sill loads, especially those due to buff, were practically eliminated. This new construction was stronger with its 21.3 sq. in. cross-sectional area than the old design of sill with an area of 28 sq. in., the same class of steel being used in both, namely, open-hearth.

In the 40-ton box car this change in sill construction effected a weight saving of approximately 1100 lb. per car. Exhaustive buffing and loading tests proved that this new sill was superior to the older sill. Welding, of course, cannot be credited with all this saving, but it played an important part.

Since then many thousand, in fact nearly all the house cars and a goodly number of the open top cars are using this double-Z-section sill which is the A. A. R. standard.

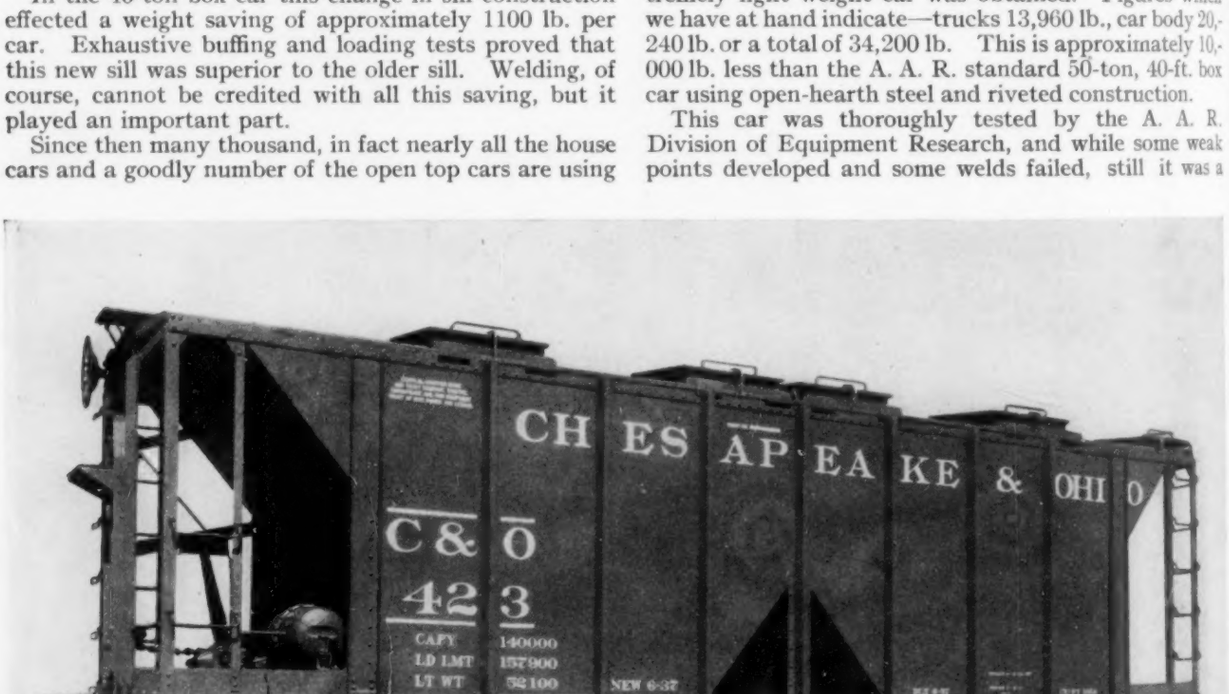
The economic advantages of handling cement as well as other dry commodities in bulk, rather than in sacks or packages, calls for specially designed equipment. The lading must be fully protected from weather and the design must facilitate quick loading and unloading.

To meet the situation, in 1932 A. C. F. designed and built a 70-ton covered hopper car. In order that the lading might be discharged freely it was absolutely necessary that the interior of this car be as smooth as possible. To accomplish this, welding was used in the joining of all members which came in contact with the lading, making possible a perfectly smooth interior. The underframe parts and the roof construction were riveted. This type of car has been very successful. A goodly number of cars constructed after this manner have been built for the handling of cement, carbon black as well as other dry bulk commodities. Without welding it would have been impossible to have obtained the necessary smooth interior necessary for the free discharge of the lading.

From this time on the use of welding in freight equipment progressed rapidly. There are numerous instances of small numbers of cars of the gondola and hopper type, in which welding played an important part.

In 1935 Pullman Co. fabricated a 50-ton welded steel box car. Alloy steels were freely used in the construction of this car. The frame members were assembled by arc welding, and the sheets were secured to the frame members by spot welding. Final assembly of the car was by means of arc welding. Due to the combination of alloy steels, both rolled and cast, as well as welding, an extremely light weight car was obtained. Figures which we have at hand indicate—trucks 13,960 lb., car body 20,240 lb. or a total of 34,200 lb. This is approximately 10,000 lb. less than the A. A. R. standard 50-ton, 40-ft. box car using open-hearth steel and riveted construction.

This car was thoroughly tested by the A. A. R. Division of Equipment Research, and while some weak points developed and some welds failed, still it was a



C & O Hopper Car

A. T. & S. F. Covered Hopper Car

well-balanced design and improvements in welding technique will remove practically all of defects due to welding.

We will not attempt to list all of the designs brought out and built during the last two or three years. They have been many and cover every class of car, as well as numerous details incorporated in car bodies and trucks.

The A. A. R. held its convention last June here in Atlantic City, the first in seven years.

A survey of the track exhibits will give a good gage of how far welding has invaded the car construction field. Among these track exhibits there were:

A light-weight box car, of a later design than the one referred to above. It was as its predecessor, of alloy steels, welded construction, but to the latest A. A. R. proposed standard dimensions. It represented about 10,000 lb. saving over the proposed A. A. R. car of open-hearth steel and riveted construction.

A steel frame, steel sheathed refrigerator car wherein practically all the steel parts were joined by welding.

Two covered hopper cars from two different roads, where the smooth interior was obtained by welding, the most of the remaining parts were assembled by riveting.

An all-welded flat car, a welded box car underframe, a welded underframe for a caboose car, etc.,

The August 7th issue of the *Railway Age*, the current one at the time this was written, describes the Delaware and Hudson activities. This shows an all-welded hopper car, and a lot of 100 box cars, again of all-welded construction.

Yes, welding has definitely been accepted as a method in freight car construction.

Tank Cars

Prior to 1927 welding was used quite extensively in the assembly of the insulation jacket, that is, the outside cover for insulated tank cars. Welded steam coil joints were fast replacing the screw connection. Isolated cases of steel tanks were constructed for experimental service.

In 1928 the Niacet Chemical Co. placed in service an aluminum tank of welded construction. This car was operated under a special permit of the I. C. C. for experimental service. By March 1930 it had a service record of 22,000 miles. This car was fitted with an impact recorder for the first 2000 hours of its operation and successfully withstood 3500 impact shocks (900 of which were severe) with no damage to the welds.

Due to the inability of the Aluminum Co. to furnish large enough sheets, 16 sheets were used to form the tank shell in place of three, which is now the practice.

Aluminum was used in this tank because steel was not suitable for the lading.

An A. C. F. welded aluminum car of recent construction was on the exhibition track at the A. A. R. convention.

Tanks used in the transportation of dangerous or corrosive liquids, must be built to specifications established by the I. C. C. The I. C. C. were non-receptive to fusion welded construction in car tanks. In 1930 the I. C. C. ruled against the use of welding for constructing spherical car tanks by welding together two spun hemispheres.

The growing need for car tanks to handle liquefied petroleum gas, which could be transported only in forge welded tanks, was viewed with envy by the fusion welding advocates. After many ups and downs, including several hearings before the I. C. C. permission was given to construct for experimental service a total of 36 tanks. This has now been increased to 312. The welds in these tanks must be X-rayed. The entire tank as a unit must be stress-relieved. This in addition to the usual hydrostatic tests.

Mine cars, of welded construction, are numerous and are giving excellent service.

Passenger Cars

What is the story of welding in the passenger train car? It was in the passenger train car that welding was first used in car construction.

Shortly after the advent of the steel passenger car many light members such as furring clips, tapping strips, etc., were attached by spot welding. Welding was also used to make weather tight joints, especially around window openings and a little later for sealing the joints between roof sheets.

One of the early examples of a passenger car welded construction is found in the Budd-Michelin Rail Car. This car construction was fabricated from extremely thin sheets of stainless steel (18–8). The Zephyrs built by the Budd Co. utilized the same type of construction, namely: trusses, formed from very thin sheets of stainless steel (18–8), joined together by a current measured spot weld.

In the two trains designed and built by A. C. F. in 1934, for the Baltimore and Ohio Railroad, the Duryea center sill construction was assembled by welding. On both

trains, that is, the alloy steel and the aluminum, the side sheets were butted together and welded.

In 1935 A. C. F. designed and constructed for the Gulf, Mobile and Northern Railroad two streamlined trains in which the outside of the cars were prefectly smooth, that is, no rivet heads appeared. The car side sheathing as well as the roof sheets were attached to their frame members by spot welding. The roof and sides were built up in reasonably short sections and assembled at the car by riveting the structural members together, the joints in the outside sheets being made by arc welding.

The absence of rivets, obtained by means of spot welding, enhanced the appearance of these cars greatly.

Practically all passenger cars constructed within the last three or four years have utilized welding more or less, in their construction. The trend is to increase the amount of welding, using the spot where possible, otherwise using the arc.

Weight saving is an extremely important factor in passenger train cars, especially where propelled by an internal combustion engine. Welding is a very important implement in this weight reduction.

Many new steel alloys have been brought forth by the various steel companies. One of the first questions the passenger car designer asks is how does this material weld.

We find that various railroad shops, as well as all of the passenger car equipment builders have built cars with welded construction.

The equipment to economically weld a passenger train car is very expensive. Large and sturdy jigs must be built on which the framing members may be laid and securely held in accurate position, for welding.

Spot welding of the closure sheets by means of automatic machines which will pass over the work held in the aforementioned jigs, is becoming the accepted method.

The heavy cast steel castings which in the past formed the end and bolster portion of the underframe, are now being supplanted by a welded construction of rolled steel shapes and plates.

Modern passenger train design calls for a structure as well balanced as the old "one horse shay." The entire structure, which in reality is in the form of a large tube, is the load carrying member.

Designers have found and are finding that welding provides the best means for obtaining this balanced structure.

Records of the last year or two make it very evident that welding has taken its place along with the riveting, in modern railway car construction.

A. C. F. with which the writer is associated recognizes the value of fusion and spot welding. Welding represents an advanced step in construction. This we have long appreciated.

There are many problems of design, equipment and personal technique, which must be solved before welding can become an economical production method.

A. C. F. has and is vigorously pursuing studies along all of these lines with the view of being fully prepared to meet this new trend.

What of the future?

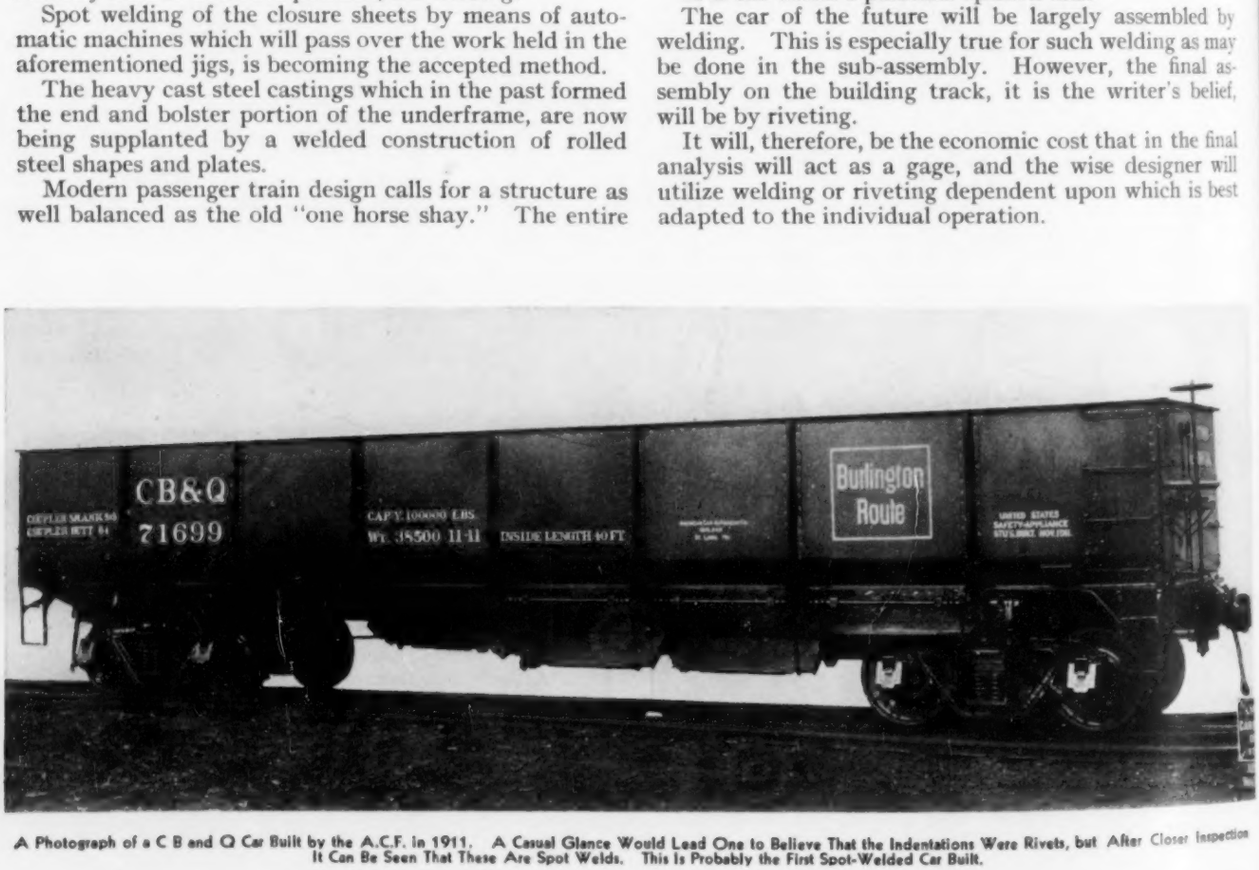
The cars of welded construction which are now in service are being watched very carefully. The service records of these cars will largely influence the future application of welding in railway rolling stock.

There is no doubt but that welding lends itself equally well to weight saving as it does in obtaining a design balance. Overlapping joints may be eliminated. Weakening of members by rivet holes will disappear. When thin sheets are riveted to their structural members it is the bearing value of the sheet on the rivet that is generally the limiting factor. By spot welding the connection can be made the full value of the sheet without any detracting from the strength of the sheet.

It is the writer's personal opinion that—

The car of the future will be largely assembled by welding. This is especially true for such welding as may be done in the sub-assembly. However, the final assembly on the building track, it is the writer's belief, will be by riveting.

It will, therefore, be the economic cost that in the final analysis will act as a gage, and the wise designer will utilize welding or riveting dependent upon which is best adapted to the individual operation.



A Photograph of a C B and Q Car Built by the A.C.F. in 1911. A Casual Glance Would Lead One to Believe That the Indentations Were Rivets, but After Closer Inspection It Can Be Seen That These Are Spot Welds. This Is Probably the First Spot-Welded Car Built.

Spot-Welding of Low-Alloy Steels*

By G. S. MIKHALAPOV†

BEFORE proceeding any further it should be stated that the rules for good welding of low-alloy steels are in no way different from those for mild carbon steel. In fact it would be well to go even further and state that the fundamental rules for welding anything from brass to nuts are the same. Accordingly, any discussion of spot-welding of low-alloy steels will be to a large extent a review of the general theory and rules of spot-welding.

There is, however, this difference between spot-welding mild carbon steel and alloy steels. The mild carbon steel is one of the most forbearing of materials. One can commit every cardinal sin of spot-welding and still get some kind of a weld. Alloy steels, however, by virtue of their comparatively high electrical resistance and low thermal conductivity are much more sensitive and require a much stricter adherence to the welding rules if satisfactory results are to be obtained.

Let us review the principals and technique essential for successful spot-welding and try to analyze what would happen if these were disregarded in welding of low-alloy steels.

Supposing we get down to fundamentals. What is spot-welding? Generally speaking, spot-welding is the joining of metal sheets or sections by means of a series of localized points of fusion. More specifically the term has come to imply not only the type of joint produced but also the process by which it is secured. Accordingly the term spot-weld now usually denotes a joint or bond of one or more sheets or sections obtained by means of a localized point of fusion produced by the effect of heat, generated by the passage of electric current through the point to be joined, and properly controlled to prevent undue vaporization and loss of metal caused by the explosion effect usually accompanying sudden formation of gas. Accordingly a spot-weld is dependent on two principle factors—generation of heat at the point of welding and the subsequent control of this heat.

The first part is simple enough. It is common knowledge that the passage of electric current through any substance will generate heat, the amount of which will be proportionate to the product of the square of the magnitude of the current and a constant, specific to the material, and known as the electric resistance of the material. Consequently, all that is necessary to satisfy the first requirement is the introduction of a flow of electric current through the point at which a spot-weld is desired, of such magnitude that the rate of the generation of the heat is faster than that of its dissipation. Unfortunately a great many people consider that their responsibility in producing a good spot-weld stops right then and there. They address the joint more or less like this: "Well, here is your current, we know it makes you hot, fuse then, you dumb so and so." If the weld shows reluctance to stick together they increase the dose of current or the time of application of the current and call it a day. If, occasionally, the metal still refuses to weld they simply go somewhere else and weld something less ornery.

Suppose we analyze what exactly does happen when heat begins to be generated in a spot-weld. Assuming a rate of generation sufficiently high to make negligible the losses through conduction into the surrounding metal, there will be a gradual and definite rise of temperature throughout the mass of metal lying within the path of the welding current. This temperature rise, however, will not be uniform but will be a function of the distance to the nearest electrode and also of the distance to the joint of the surfaces being welded. Two things enter into this relationship—the rate of generation of heat and the rate of its loss through the highly conductive and comparatively low temperature electrodes. The former is at its maximum at the junction between the surfaces being welded and the latter is obviously directly proportionate to the distance from the nearest electrode. The relative importance of these two factors depends on the welding time used, the shorter the time the more important the former as the contact resistance decreases rapidly as soon as some fusion occurs. We have then a certain mass of metal increasing in temperature at a comparatively high rate in its center and at a gradually declining rate as the surface is approached. As the temperature increases, a time will eventually come when at the point of the highest rate of increase the metal will become a liquid. Any subsequent increase in the temperature will tend to transform the liquid metal into a gaseous state, and then increase the internal pressure of the gas until it becomes sufficient to separate the surfaces being welded and allow all or part of the gas to escape forming, so to say, a miniature explosion. In doing this the escaping gas may carry with it a good deal of the surrounding metal which, because of the uneven rate of temperature increase, is still in liquid or semi-liquid state, out of the weld. If the weld is now allowed to cool, either the remaining high-pressure gas will, on contracting, form a cavity or if the magnitude of the explosion is such that most of the gas and liquid escapes no weld whatsoever will result.

It is important to note that the factors tending to produce gas and increase the internal pressure will depend on two things. First—the depth of desired penetration of fusion (that is, the distance from the highest temperature point to the outer limit of the metal which has reached molten state), and second—the difference in the rate of increase of temperature throughout the weld.

The first is fixed by the strength requirements of the weld and is very nearly a constant for any given combination of sheets or sections. The second, however, is a variable and is essentially a function of the properties of the metal being welded, namely, its surface resistance and its thermal conductivity. The higher the surface resistance the greater will be the difference in the rates of the heat generation at the junction of the surfaces being welded and in the metal itself. The lower the heat conductivity of the metal the greater the difference between the heat loss at each welding electrode and at the center of the weld. Hence, the higher the former and the lower the latter the greater the difference in the rate of temperature rise throughout the mass welded.

In so far as all alloy steels have considerably lower heat conductivity than mild carbon steel, it is to be expected

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† *Welding Engineer*, Heintz Manufacturing Company.

that the tendency to form high-pressure gas pockets before sufficient metal for an adequate weld has been fused, will be more pronounced in low-alloy steels. This is definitely the case and unless the heat generated is carefully controlled and this tendency is properly checked very poor and porous welds will result.

Let us now consider the second requisite of spot-welding, namely, the control of the effects of the heat inside the spot-weld. As we have already seen, the difference in the rate of increase of temperature within the weld tends to produce a high-pressure gas pocket in the center of the weld before the outlying metal has had a chance to melt. There are two obvious ways to deal with this problem. The first is to cease any further generation of heat as soon as the temperature at the hottest point exceeds the vaporization temperature of the material. Unfortunately the temperature gradient may be, and in case of alloy steels actually is, sufficiently steep to make the volume of metal at fusion temperature surrounding the just-below-the vaporization temperature center so small that if the weld is allowed to cool then a very small and structurally weak bond would result, in practically all cases except, perhaps, in those of the very thin sheets.

The second method is to inhibit the vaporization of the metal in the center of the weld by preventing the expansion requisite for transformation of a liquid into a gas. This is usually accomplished by applying an outside force to the parts welded of the magnitude sufficient to prevent any opening of the surfaces and any deformation of the orginal shape of the parts joined, with the result that the expansion accompanying any gas formation is inhibited and the boiling or vaporizing temperature of the metal is raised sufficiently to allow the metal at a required distance from the center of the weld to reach melting temperature, thus forming a pool of liquid metal of desired magnitude but without any gas inclusion.

This is briefly the function and purpose of what is generally known as the welding pressure. Contrary to the popular conception it does not squeeze the molten or plastic metal together but, by preventing expansion, it raises the vaporizing temperature of the metal and thus, allows the formation of a welded bond of sufficient magnitude.

It will be remembered that because of its lower heat conductivity alloy steel spot-welds have much steeper temperature gradient than mild steel spot-welds. We can, therefore, now conclude that they will, in general, require higher pressures than the mild steel spot-welds, and that any departure from the correct values will result in the formation of much poorer welds than in the case of mild carbon steel. Experience shows that this is correct and that low-alloy steels require from 50 to 100 per cent higher welding pressures, depending on the thickness welded.

We have already seen that the increase in the surface resistance of the metal, by increasing the amount of heat generated at the juncture of the surfaces being welded, increases the unevenness of temperature in the weld. In alloy steels where the conditions are already bad it becomes doubly important to reduce this resistance as much as possible. Presence of grease, dirt or scale may aggravate the condition to the extent where even considerably increased pressure will not prevent formation of gas pockets and blow holes. All scale particularly should be carefully removed, as its resistance appears to be greater than that of mild steel.

It is common knowledge that the pressures used in welding mild carbon steels are comparatively very low. Except for very heavy gages, a pressure of but a few hundred pounds is usually sufficient. This means that in thin sheets the rate of temperature increase is very nearly uniform throughout the weld. It then follows that an appreciable increase in the rate of the temperature increase may be made before the temperature gradient becomes sufficiently steep to demand an appreciable increase in pressure. Little objection has then been raised to the present tendency in the spot-welding of mild steel toward shorter and shorter welding periods. True, as these have reached the rate of but a few cycles the pressure had to be increased somewhat, but in no case to a degree where any appreciable inconvenience to design or operation is experienced.

Consequently the attitude usually found between the welders of mild steel, particularly in the form of thin sheets, is that the shorter the welding period the better. The shorter the welding time the greater the number of spots per minute and, consequently, the greater the speed of welding.

In the case of alloy steels, however, an excessive shortening of time may require pressure of inconveniently high magnitude. For this reason the welding periods used are as a rule of medium length, 8 to 10 cycles being about the limit.

So far, attention has been drawn to the difficulties encountered in spot-welding low-alloy steels. However, they possess one definite advantage over the mild carbon steel in so far as welding is concerned and that is, everything else being equal, they require less welding current and, therefore, less welding capacity. The very same characteristics which required higher welding pressures, namely, the comparatively low thermal conductivity and high electrical resistance, permit the same generation of heat with less current, both because the actual heat produced by the passage of current through the steel is higher and because the losses through the absorption of heat by the metal surrounding the weld are lower.

In general it can be said that the current requirements for spot-welding low-alloy steels are between 30 and 50 per cent lower than for mild carbon steel.

In conclusion a few words should be said on the subject of spot-welded design of structures utilizing low-alloy steels. Theoretically the only difference between the low-alloy and mild carbon steels, so far as stress analysis and structural design are concerned, is the higher ultimate and yield points of the former. Fundamentally this is true, but one aspect of the higher yield point not at once obvious is the stressing of spot-welds considerably over and above the normal increase due to the increased loads and stresses used.

For instance, supposing a structure is designed to be built of low-alloy steel with stresses 40 per cent higher than if mild steel were used. We would expect then that the stresses on the spot-welded joints would be also 40 per cent higher and that if the total strength of spot-welds used were made 40 per cent greater all would be well.

Basically this assumption is correct in so far as the total load on any one joint or unit area of a joint would be increased only 40 per cent. However, individual spot-welds may be stressed considerably higher and in addition still higher stress concentration may occur at different parts of each spot-weld. This is due principally to the greater stiffness of the low-alloy steels and sections, which makes more difficult the uniformity of load distribution between the spot-welds and also makes for points of concentrated stress on the areas of individual welds. A good illustration of this fact can be obtained by considering first two sheets of rubber and then two of glass fastened together at point intervals by some means approximating spot-welds. If an attempt is then made to pull the two sheets apart it becomes apparent that no matter at what angle or direction the load is applied to

the rubber sheets it will become distributed fairly uniformly between the points of fastening. In addition, irrespective of the direction of load the points of fastening will be always in the same kind of stress. In the case of the two sheets of glass, however, the angle and point of application of the load will determine the magnitude and type of stress on each point of fastening.

The above does not mean that the low-alloy steels are less suited for spot-welded design than mild carbon steel, but simply that a different design technique must be followed. It also means that the strength of spot-welds must be more accurately known and controlled.

In other words, spot-welding in alloy steel structures must cease to be a haphazard hit-or-miss proposition and become an exact and accurate science.

Welding Low-Alloy Steels*

(Opening Remarks for A. W. S. Symposium)

By A. B. KINZEL†

CRITICAL discussions of the welding of low-alloy steels together with presentation of data pertaining to the newer type of low-alloy structural steels have not been wanting in the past few years. The publications of Warner, Gillett, Chapman, Hodge, Hopkins and Gibson, as well as numerous articles by the writer, cover the field. In addition, there are a great number of articles by steel producers and others too numerous to mention. Thus, there is no lack of data, fact and opinion in this field. One purpose of any symposium is to clarify the facts and properly weigh the opinions. The AMERICAN WELDING SOCIETY Committee on Weldability of Low-Alloy Steels is presenting a report at the current annual meeting. In this report much of the data is organized and should prove to be a valuable adjunct for purposes of discussion.

A more fundamental purpose of any symposium is to stimulate thought in a given field of activity. Accordingly, instead of summarizing at this time the literature and experience to date, an attempt will be made to postulate the problems involved and briefly sketch the current industrial picture.

The first problem is implied in the statement that welded joints must be tough. Toughness used in this sense involves chiefly ductility under static and dynamic conditions, and applies to all portions of the joint, be the zone in question ever so narrow. One type of zone which may be produced in the welding of low-alloy steels and which may not have the requisite toughness is that zone adjacent to the weld which has been subjected to rapid cooling from above the transformation temperature of the steel. The nature of this zone is a function of the air hardening properties of the steel, and as a result there has been a strong tendency for the uninitiated to use hardness as a criterion of the properties of this zone. This involves the assumption that hardness and lack of toughness are synonymous. Such an assumption is tenable when discussing plain carbon steels, and it is even tenable when discussing very large changes in hardness of low-alloy steels. But the whole purpose of alloying structural steels is to obtain greater strength or hardness without sacrificing ductility or toughness. Thus, extra care should be taken when considering low-alloy steels not to confuse the issue on this score.

The second problem in the application of low-alloy steels involves strength, that is, the joint must be as strong as the base metal. Assuming toughness, this really is no problem at all if we consider only the tensile strength ranges in vogue today. The annealing effect on welding low-alloy steels is small enough, so that decrease in strength on this score is of no moment, and both gas and electric welding rods have been developed which adequately meet the requirements for the deposited metal.

Another problem involves dependability of the joint, and this reduces to simple mechanical soundness. This problem is solved by good engineering. Well-designed joints made with previously tested welding rod or electrode known to have satisfactory welding characteristics under a wide range of conditions are readily made by qualified welders. The alloy content of the low-alloy steels offered to the trade today is low enough and of such a character as to introduce no problems from the standpoint of fluidity and slag control.

The next problem involved is the uniformity to be expected in welding materials of varying thickness and under varying conditions of design. At the present time this problem is well in hand from the welding standpoint, although many of the low-alloy steels offered to the trade are available only in sheet and plate of relatively small thickness. This seems to be a manufacturing and commercial problem rather than a welding problem.

The last problem which we choose to postulate at this time concerns the toughness of the structure as a whole, as distinct from toughness of the joint proper. This may be restated as the question of internal stresses. Because low-alloy steels have higher strength than ordinary steel, because this higher strength involves higher yield strength not only at room temperature but at moderately elevated temperatures, and because the low-alloy steels are used in structures in which rigidity is obtained by selective distribution of material rather than by mere mass, the problem of internal stresses is more acute and must be given more serious consideration with the low-alloy steels of a given section than with the carbon steels. It is not the purpose of this article to enter into this controversial subject, except to point out that the higher the strength, the lighter the material for a given stress and the less chance for trouble from internal stresses. Thus, the mild disadvantages of low-alloy steels cited above are offset by this major advantage.

The welding of low-alloy steels today is an accepted practice. A great variety of steels are available, any one of which is suitable for welded construction. Those steels in which the carbon is kept below 0.15% and the ultimate strength below 80,000 psi are classified as foolproof, in that when used in light gage all of the problems above mentioned are adequately met. Those steels having higher carbon content and an ultimate strength not in excess of 95,000 psi, as well as the lower carbon steels in heavier gage, likewise may be used with complete satisfaction with respect to the above mentioned phases provided stress relieving is applied.

Briefly then, the general solution of the problem of welding the low-alloy steels of today can be stated as follows. Apply intelligent welding practice and follow the same principles as in the welding of carbon steel. Apply similar standards and tests as a measure of the results. It should be realized that after all, the welding of low-alloy steels is a very small step beyond the welding of plain carbon steels and that welding can, therefore, be adapted to such steels in the same manner and in the same degree.

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* To be presented at Annual Meeting, AMERICAN WELDING SOCIETY, Atlantic City, Oct. 18–22.

† Chief Metallurgist, Union Carbide & Carbon Research Corp.

WELDING Marches On!

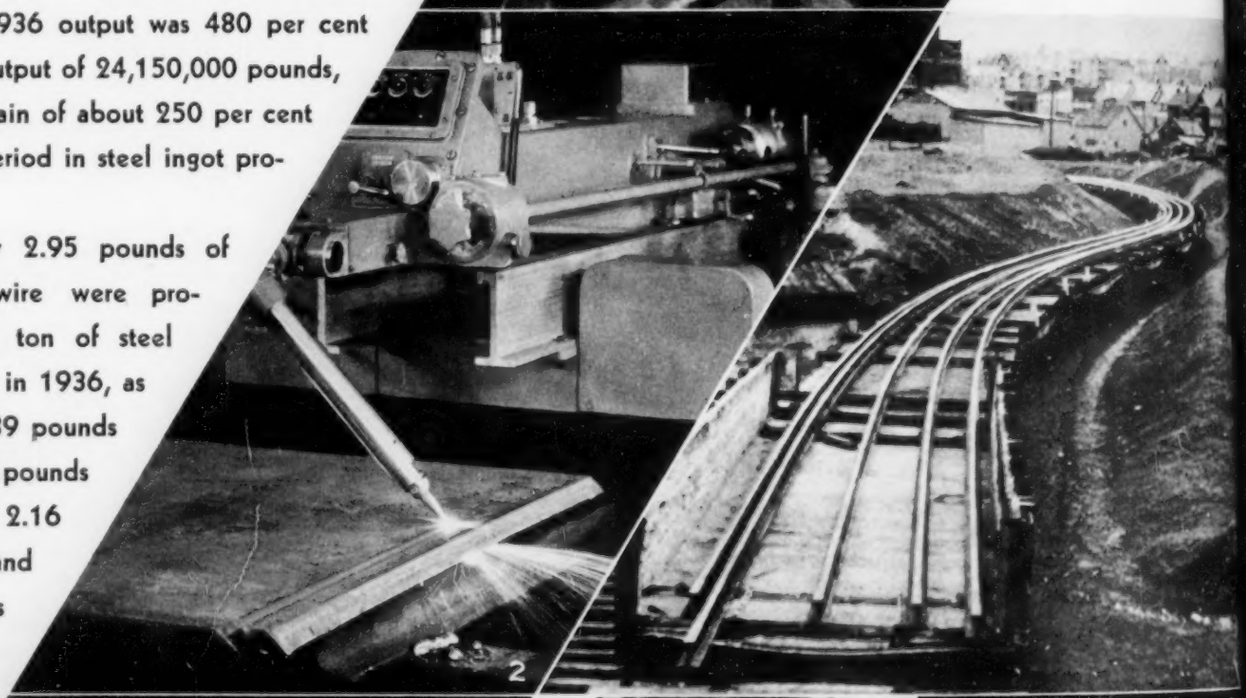
The Sunday Edition of the *New York Times*, September 18, 1937, carries the following statement:

"Over 140,000,000 pounds of steel welding wire were produced during 1936, or enough to make a strong weld 134,000 miles long, according to estimates made by the American Iron and Steel Institute. The 1936 output was 480 per cent over the 1932 output of 24,150,000 pounds, compared to a gain of about 250 per cent over the same period in steel ingot production.

"Consequently 2.95 pounds of steel welding wire were produced for each ton of steel ingots produced in 1936, as compared to 2.89 pounds in 1935, to 2.78 pounds in 1934, to 2.16 pounds in 1933 and to 1.79 pounds in 1932."

3. Production Welding of Refrigerator Parts Is Speeded by the Aid of Suitable Jigs.

Courtesy The Linde Air Products



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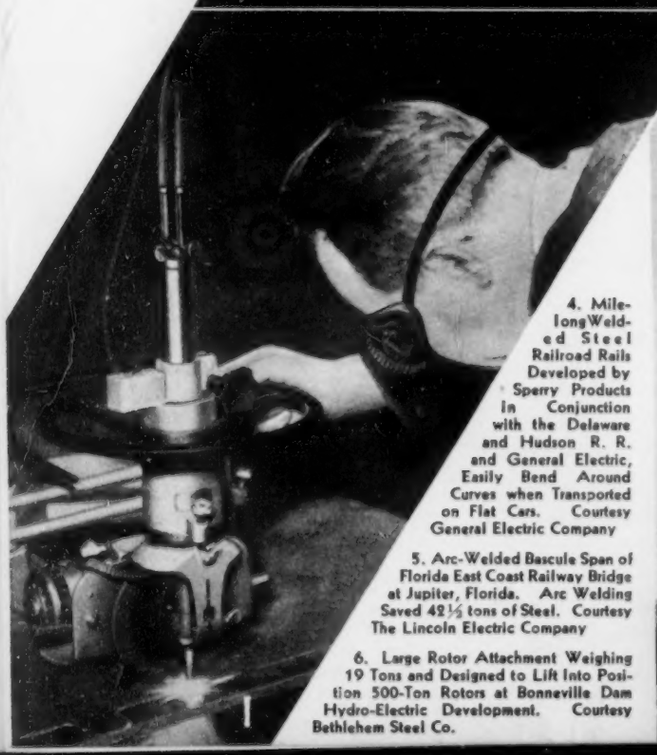

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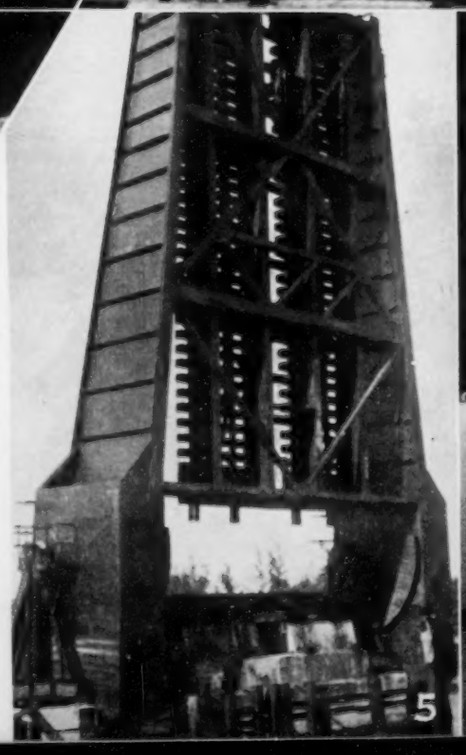
4. Mile-long Welded Steel Railroad Rails Developed by Sperry Products In Conjunction with the Delaware and Hudson R. R. and General Electric, Easily Bend Around Curves when Transported on Flat Cars. Courtesy General Electric Company

5. Arc-Welded Bascule Span of Florida East Coast Railway Bridge at Jupiter, Florida. Arc Welding Saved 42½ tons of Steel. Courtesy The Lincoln Electric Company

6. Large Rotor Attachment Weighing 19 Tons and Designed to Lift Into Position 500-Ton Rotors at Bonneville Dam Hydro-Electric Development. Courtesy Bethlehem Steel Co.



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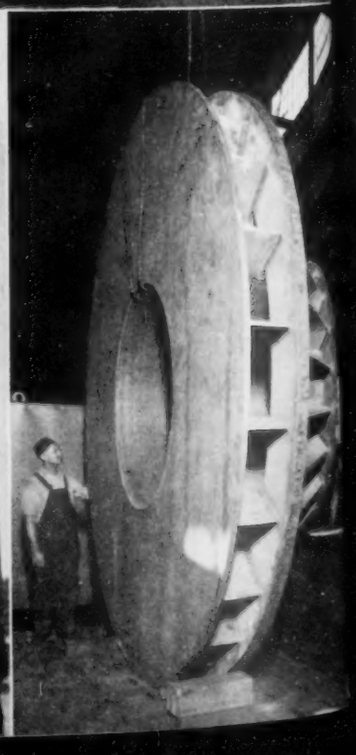
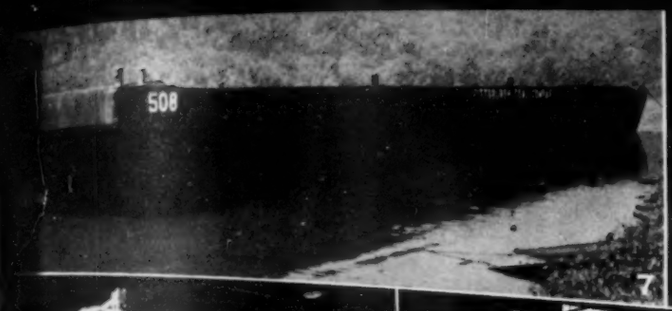
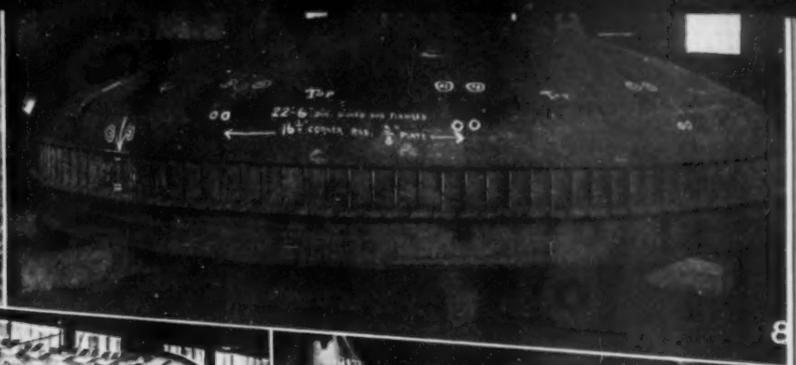
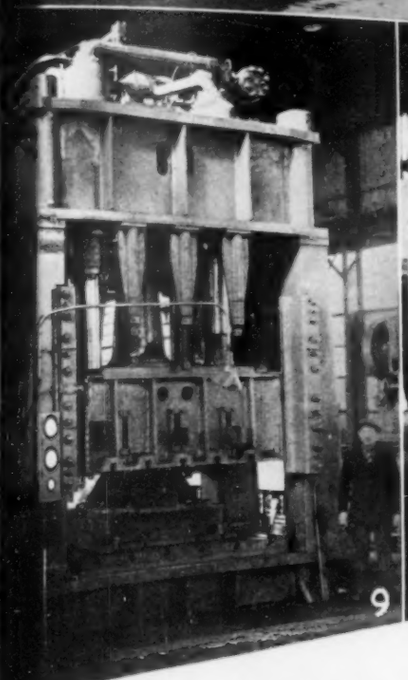
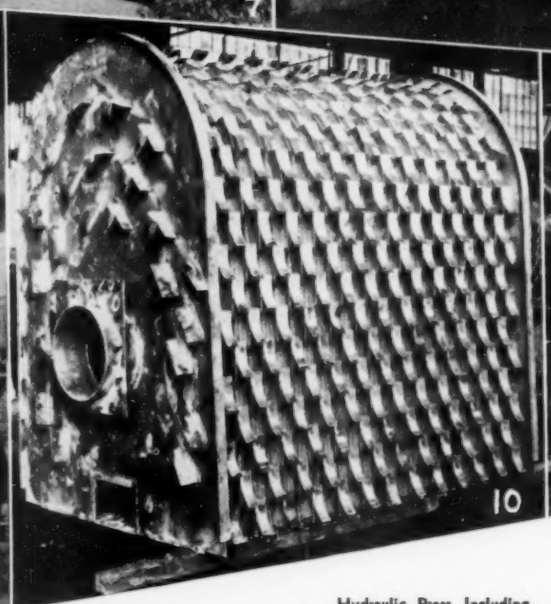


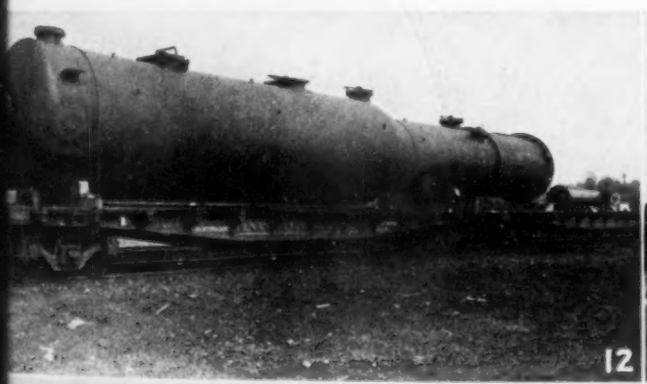


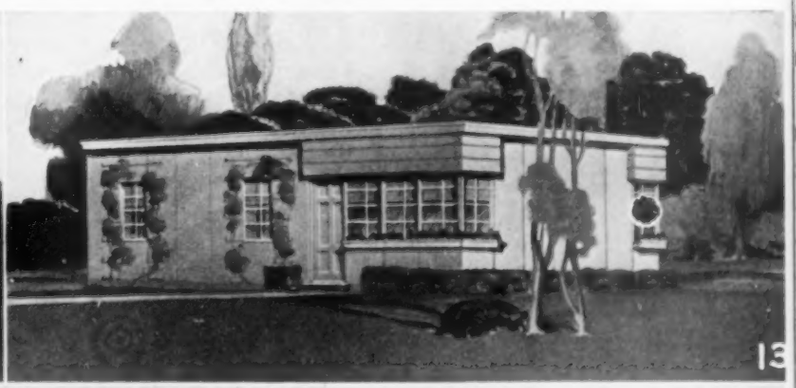


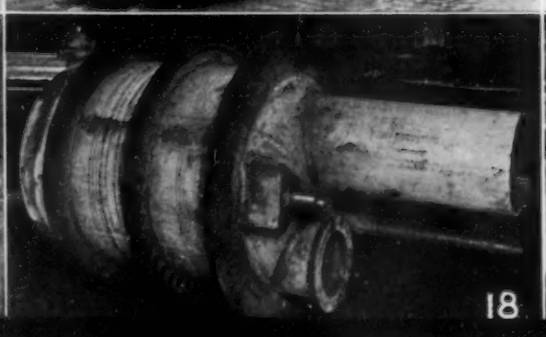


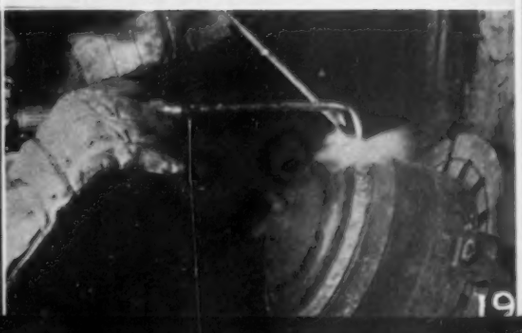


7. Welded Steel Hopper Coal Barges. The Barges Are 175 Feet Long, 26 Feet Wide and 11 Feet Deep. Weighing 150 Tons Each Barge Has a Capacity of 1000 Tons. Courtesy Westinghouse Electric & Mfg. Co.
8. Large All-Welded Cover Fabricated by Ohio Machine and Boiler Company. Courtesy The Champion Rivet Company
9. The Entire Frame of 800-Ton Baldwin-Southwark Hy-Speed Hydraulic Press, Including the Side Members, Upper Super-Structure and Oil Storage Tank at the Rear of the Press Were Fabricated by Lukenweld, Inc., of Welded Steel Construction
10. Unit Heater Distributed by Dravo Doyle Company. Welded Construction Increased Heating Efficiency to 87% (gas fired)
11. Double Deck Wire Reels of Welded Construction, Illustrating Low Cost Equipment Designed of Steel Castings and Welded Plate. Courtesy The Wellman Engineering Company
12. Large Welded Pressure Vessel. Courtesy Petroleum Iron Works
13. One of the Harnischfeger Welded PRE-FAB Homes
14. Heavy Duty Truck with Body Fabricated Entirely by Shielded Arc Welding. This Truck Was Built by the Hug Company. Photo Courtesy The Lincoln Electric Company
15. Streamlined Tug Boat Constructed by Electric Welding by Lester F. Alexander Co., Inc.
16. This 70-Ton Arc-Welded Steel Quadruple Hopper Car with Cast Steel Under Frame Was Built for the Kansas City Southern Railway by the Mt. Vernon Car Manufacturing Co. Courtesy The Lincoln Electric Company
17. Bronze-Welding Locomotive Frame. Courtesy Air Reduction Sales Company
18. Lead Extruding Kettle Used in Die Casting and for Melting Metal to Be Extruded Into Dies. Weight 3660 Lb. Courtesy Bethlehem Steel Company
19. Hard-Facing the Seating Surfaces of Valves for Handling High-Temperature, High-Pressure Steam. Hard-Faced Valves Have from 6 to 10 Times the Life of Ordinary Valves. Courtesy Haynes Stellite Company









Power Supply for Welding*

By A. S. DOUGLASS† and L. W. CLARK‡

THE rapid increase in the use of welding as a fabricating process merits the attention of the electric power industry. Though welding in itself produces very little revenue as compared with other classes of load, and certain types of welding load are intermittent and highly disturbing, it is, nevertheless, a major and indispensible tool of many of the utilities' largest customers. There are certain interesting problems involved in providing satisfactory service to some types of resistance welder loads.

The interest of the user of welding is to secure suitable service at the lowest possible cost for extra power facilities and without excessive expenditures being undertaken in what may prove to be ineffective changes in his plant distribution system.

The authors are of the opinion that very little has been published relative to either the energy consumption or service phase of this problem. The paper presents the results of an attempt to evaluate the metallic arc, gas and resistance-welding load of a large power company in terms of kilowatt-hour consumption. Whereas no problem is ordinarily encountered in serving the arc or gas welding load, certain problems of mutual interest to both the power company and the customer are frequently encountered in serving resistance welding loads, and these are discussed.

The determination of the energy consumed by each of the three types of load has necessarily involved the making of numerous estimates and assumptions, and the results can only be accepted as closely indicative rather than exact.

Energy Consumed by Arc Welding Load

The estimated total consumption of electric energy for arc welding for the year 1936 is over 16,000,000 kwh. The figures used in arriving at this estimate are as follows:

Electrode consumption, pounds	6,500,000
Kilowatt-hours per pound of electrode	$2^1/_2$
Total kilowatt-hours	16,250,000

The figure chosen as representing the electrode consumption, in pounds, is the average of the estimates from two reliable sources, the lowest of which was 5,000,000 lb. and the highest 8,000,000 lb. The figure is slightly less than 6% of the published figure of 111,000,000 lb. of electrodes manufactured in the United States in 1936.

The kilowatt-hours represented by the consumption of one pound of electrodes depends, to a great extent, on the welding rate which is maintained, or in other words, on job conditions. According to tests, using a 300 ampere, motor-generator type welding machine, approximately 1.5 kilowatt-hours is chargeable directly to consumption of the electrodes. The amount to be added, which is chargeable to running losses of the machine, varies from approximately 1.1 kilowatt-hours per pound for a melting rate of 2 pounds per hour to 0.2 kilowatt-hours per pound for a melting rate of 10 pounds per hour, as shown in Fig. 1. The total average figure used in the calculation, 2.5 kilowatt-hours per pound, corresponds to a melting rate of $2^1/_4$ lb. per hour, which is considered a fair assumption based on careful observation of actual shop welding.

No subtraction was made for electrodes consumed by gasoline-driven welders, as it was felt that this figure would be offset by energy consumed in carbon-arc welding in which no filler metal is used.

Energy Consumed by Gas Welding Load

The kilowatt-hours used by gas welding load admittedly is an indirect one, but it is no less real on that account. It exists by reason of the fact that plants supplying gases for welding utilize electric energy in manufacturing those gases and making them available to customers in appropriate containers.

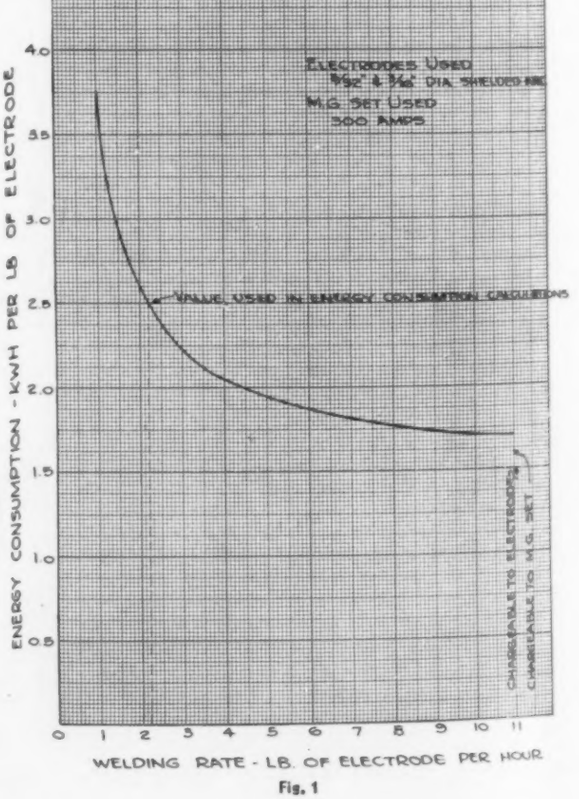


Fig. 1

* To be presented at Annual Meeting, AMERICAN WELDING SOCIETY, Atlantic City, Oct. 18–22.

† Construction Engineer, The Detroit Edison Company.

‡ Engineer, Electrical System, The Detroit Edison Company.

The estimated total energy consumed by that load for the year 1936 is 7,000,000 kwh., which is 60 per cent of the total energy consumed in the district in the manufacture of gases for all industrial purposes, largely welding and cutting. This assumption of 60 per cent of the total being utilized for welding is, of course, open to question and not subject to proof.

Energy Consumed by Resistance Welding Load

Fortunately for the users of resistance welders, the power consumption is a relatively small factor in the total cost of operation. For certain seam welders the power consumption does become more noticeable due to the more continuous nature of the load. Now, if resistance welders presented no problem from the standpoint of providing adequate service, the power companies would not be particularly disturbed by the apparent lack of revenue as indicated by a low kilowatt-hour consumption; but due to the high peak, low power factor loads, they are often faced with the necessity of bolstering up feeds, increasing substation capacities, and generally strengthening their distribution systems in order that welder load swings will not prove disturbing to other good customers, and even more so to the welding customer himself.

Although the individual welder admittedly uses very little energy, does the aggregate or total energy consumed by all resistance welders on a power system amount to any appreciable value? In order to better answer this question a series of surveys and tests have been made to determine just how much revenue does accrue from this type of load. A detailed survey of some large automobile plants, along with conservative estimates covering other industries in the area, indicate a connected load of resistance welders of about 500,000 kva., served by a power system with a firm capacity of some 750,000 kw. These are startling figures. The figure of 500,000 kva., is strictly an estimate, but is presented as a conservative value with the knowledge that estimates from other sources all point toward a considerably higher value.

In order to convert this into terms of kilowatt-hours, tests were made in a large accessory plant having an hourly maximum demand of about 3000 kw. and an annual consumption of about 10,000,000 kwh. This plant had 7550 kva.[1] of resistance welders of all types used in regular production work. By segregating all welder circuits from the rest of the plant load for a period of several days, it was possible to get readings of kwh. and average power factor for the welder load only. During the test period, the welder load amounted to 15,200 kwh. at 26% P.F. while the plant power and lighting load, consisting of 4600 kva. connected, amounted to 170,800 kwh. at 80% average P.F. Assuming the same ratio to hold true throughout the year, the welders used 850,000 kwh. per year and the general power and lighting load 9,150,000 kwh. This shows an annual consumption of about 100 kwh. per kva. of connected welder load as compared with about 2000 kwh. per kva. of connected general power load. Other tests for smaller installations, such as in miscellaneous repair shops not in steady production, have shown values of only 40 kwh. annual consumption per kva. of connected welder load and 500 kwh. annual consumption per kva. of connected general power load.

On the basis of 80 kwh. annual consumption per kva. of connected welder load, which is thought to be a fair average as the bulk of the welders are in large production plants, the 500,000 kva. connected load will use about 40,000,000 kwh. annually. This perhaps is an imposing figure in kilowatt-hours consumed, but the corresponding consumption from the same amount of connected power and light load would be ten to twenty times as great.

It is perfectly obvious from this comparison that expenditures for system extensions and expansions to handle welding load only cannot be justified on the basis of expected revenue in anywhere near the same proportion as is true for general power and light load. Consequently, every effort should be made to serve new resistance welding load from existing facilities, perhaps by some simple rearrangement of these facilities or by suitable load segregation as will be discussed later.

[1]

3—600 kva.	Flash Welders	—1800
3—450 "	" "	—1350
1—450 "	Projection Welders—	450
3—400 "	" "	—1200
2—300 "	" "	— 600
1—250 "	Seam Welder	— 250
1—250 "	Projection Welder	— 250
2—125 "	Spot Welders	— 250
14—100 "	Projection Welders	—1400
	Total	7550 kva.

Total Kilowatt-Hours from Welding Load

The estimated annual kilowatt-hours from the three types of welding loads are summarized as follows:

Arc Welding	16,000,000 kwh.
Gas Welding	7,000,000 kwh.
Resistance Welding	40,000,000 kwh.
Total	63,000,000 kwh.

While individual resistance welders may not use much electric energy in proportion to their connected loads or demands, the total use of energy by all types of welders combined is of substantial magnitude.

Metering Resistance Welding Load

The question is sometimes asked as to whether the induction watt-hour meter actually records the full amount of energy used by the ordinary resistance welder where the use of current may be for periods of only a few cycles. As a comparative measurement on various sizes of spot welders, oscillographic readings of the watt input were converted to watt hours based on the duration of each weld in cycles. Individual oscillographic readings are naturally subject to slight reading and calibration errors, but by totaling a large number of readings such errors tend to cancel and a reasonable check is obtained.

Table 1 shows the results of energy measurements taken on six spot welders ranging in size from 12½ to 50 kva., operating throughout their entire range of voltage taps and with different gages of metal being welded. The kilowatt-hours per weld were measured by a standard rotating induction watt-hour meter and the watts recorded by an oscillograph. The resulting comparison showed appreciable differences on the individual readings of each weld, but totaling the energy consumption as measured by both methods for thirty welds per machine or a total of 180 welds, the total difference was negligible.

Power Supply for Resistance Welders

Resistance welders present a type of electrical load which is inherently difficult to serve, from the standpoint both of the power company supplying service and of the industrial plant in which the welders are to be operated.

A few spot welders scattered about a large plant offer no particular problem, but with projection and flash welders becoming increasingly common in sizes of one and two thousand kva., single phase, a carefully designed

Table 1—Energy Consumption of Spot Welders as Measured by Induction Watt-Hour Meters Compared with Calculations Based Upon Oscillographic Measurements

Welder Size	No. of Welds Measured	Average Kva. Per Weld	Average P. F. Per Weld	Average Duration of Weld in Cycles	Watt-Hours From Induction Watt-Hour Meters	Watt-Hours From Oscillographic Measurements
12½	30	20.7	57.7	44.9	72.3	76.3
50	30	50.0	42.7	16.2	54.4	49.5
20	21	18.5	48.1	14.8	13.1	13.9
20	9	30.7	53.4	42.9	29.6	30.9
15	21	11.3	63.2	14.4	10.9	11.7
15	9	46.2	57.5	33.9	40.0	40.1
50	30	43.7	41.5	24.6	65.8	66.3
25	30	30.2	42.0	47.6	95.1	98.4
	180				381.2	387.1

system of power supply is necessary if good production with high quality welds is to be maintained. Welder load, being intermittent, usually of low power factor, and reaching exceedingly high peak values for very short periods of time, obviously will cause lamp flicker or voltage regulation troubles unless care is exercised in planning the electrical service. Thorough planning, with the resultant assurance of satisfactory results, is primarily dependent upon complete cooperation between the manufacturer of the welder, the user of the equipment and the representatives of the power company.

The remainder of this paper will present the various aspects of the problem and show how it has been met in the Detroit Area. Perhaps Detroit has been fortunate in that there are great numbers of large resistance welders in operation, particularly in the automobile and accessory plants, thus allowing considerable experience to be gained in the industrial areas where substations are large and power lines relatively short. However, even under such relatively ideal conditions, occasional troubles have been encountered which emphasize the need for careful consideration of every installation, whether large or small, to insure freedom from operating difficulties.

Welder service divides naturally into two sections, that which is part of the power company's system and that which is part of the industrial plant. Voltage regulation is the dominant problem for both parts, but for slightly different reasons. In the plant, the regulation must be good in order that two or more welders accidently operating at the same instant do not pull the voltage down to such an extent as to jeopardize the quality of the welds of either machine. On the other hand, the power system regulation must be good in order that the voltage dips are not sufficiently great to disturb lighting customers with annoying lamp flickers.

Power System Limitations

The amount of fluctuation that can be allowed, based upon allowable lamp flicker, depends to a large extent on its frequency of occurrence. Tests show that flickers, or voltage changes caused by instantaneous changes in current, become noticeable under ordinary reading conditions with 40 and 60-watt lamps at about 2 volts on 115-volt circuits. Therefore, this must be the maximum allowable on lighting circuits for rapidly recurring flickers such as caused by welders. "Power line" customers buy essentially power and consequently a greater flicker is tolerated (three or four volts) than on distribution circuits where the predominating load is lighting. These limits apply in common to practically all resistance welders, except seam welders. Certain seam welders operate with an intermittent power supply resulting in fluctuations with a frequency of 8 or 10 cycles per second. Lamp flicker becomes annoying for much lower values of voltage dip when the change occurs at this rate and the limit becomes about ¾ of a volt instead of 2 volts for the same degree of annoyance.

Methods of Service

Providing satisfactory welding service consists essentially of finding the lowest cost point of service which will be of ample capacity to keep the voltage flickers within the specified allowable limit. About 1% of the resistance welders on the system are in plants of relatively small size which buy secondary power. For this type of customer, providing a welder service usually consists of hanging a separate transformer to serve only the welder load. Such welder installations seldom are large enough to be disturbing on the 4800-volt primary lines, but every case must be checked individually to insure freedom from flicker complaints at neighboring customers. In suburban areas, and in certain city areas, welder installations are sometimes proposed which would definitely prove disturbing if fed from the regular distribution system. This necessitates either special transmission facilities or a special motor-generator set, obviously at the expense of the customer.

The bulk of the resistance welders are located in industrial plants of over 100 kw. demand, where power is purchased at 4800 volts on the primary rate. As with secondary customers, the size of welder that can be served without changes in the normal feed depends very much upon the location with respect to the power company's substations. If there are several customers fed from a single power line, the four-volt flicker limit determines the allowable welder size at any one of the customers.

If a customer is large enough to warrant an exclusive power line, the flicker limits no longer apply, except as to the voltage disturbance on the substation bus serving the power line. Customers who may be very critical regarding voltage flickers caused by others are usually more tolerant toward the same flickers if they are caused within their own plant, knowing that considerable expense on their part would be necessary to correct them. However, in some cases where the customer cannot subject his regular plant load to the disturbances set up by his own welders, it becomes necessary for him to invest in a separate additional power line to serve only the welders.

The large customers served by two or more power lines are particularly fortunate in being able to segregate their welder load from their regular plant load and serve it from the stand-by or throw-over power line which is normally unloaded. Unless there are great numbers of

welders, the effective heating load will be negligible and so not detract from the value of the stand-by cable for carrying plant load in case of failure of one of the regular lines. Tests show that a group of welders in regular production will cause a heating load of only 5 to 15% of the sum of their connected loads. Thus, a throw-over power line of 3000 kva. capacity could serve, for instance, about 10,000 kva, of connected welder load and still serve as stand-by for about 2000 to 2500 kva. of regular plant load. In these cases, the limit as to welder size becomes whatever the substation bus can handle without exceeding the two-or three-volt flicker limit. If a customer is in a large industrial area served by large substations, he can be provided with service for much larger welders than if his plant is in a residential or suburban area where the substations are small.

If the voltage disturbances on the substation bus are in excess of accepted standards, and if the substation has some excess capacity, it is sometimes possible to set aside a separate transformer and bus section for serving the welders until that capacity is needed for power load. In an industrial center of any magnitude there is often sufficient arc furnace and welder load to make it economical to set aside one or more bus sections per substation for these so-called "bad" loads. By grouping such loads and keeping all lighting and "good" power loads off this bus, the need for keeping the voltage fluctuations within standard limits often can be avoided and there still will be a reasonable load for the bus section set aside. Fortunately for resistance welders, arc furnaces which are usually good revenue producers fall in the same class as welders as far as being a disturbing type of load, and as soon as a "bad" bus is established in a given area to serve furnace load, it also becomes available for welders.

There has been sufficient fluctuating load, including both furnaces and welders, in the central industrial area of Detroit to warrant temporarily setting aside special buses in 6 out of 14 substations serving this area. In these areas large welders can be served if the customer will assume the expense of a separate welder power line or can utilize his throw-over power line for this purpose and have it served from a "bad" bus. Welder customers connected to this bus, however, understand that it is temporary and that they will be required to provide motor-generator sets when the company needs the bus for power loads.

A study of the foregoing shows the methods that can be employed by a power company in serving large resistance welders without greatly increasing the capital expenditures for providing the service. However, for each location there is a very definite limit as to the size of welder that can be served; true, it may be quite large for certain favorable locations but there are a great many other areas where only the relatively smaller size welders can be handled without expensive power line extensions or motor-generator set installations.

Welder Power Factor

Welder power factor and the amount of reactive loss in welder circuits are time-worn subjects that have been thoroughly discussed in past years. Nevertheless, they are extremely important factors which must be considered in the design of the power supply for the welders.

For example, a local plant purchased two projection welders from different manufacturers to be used on identical work. One welder performed satisfactorily while the other could not produce good welds because of an excessive voltage drop in the supply circuit to the machine. The reactive loss in the second welder was higher than necessary and could easily have been reduced by a more compact design of the secondary circuit. Thus, to produce the same quality of weld, the welder user must invest more money in transformer capacity and heavier bus construction to offset the lower power factor operation.

A great majority of the large present-day flash and projection welders are of a design (in some cases of necessity) having a generous distance between the welding dies and the built-in transformer, resulting in a large magnetic loop and high reactive losses. In the vast majority of cases it does not seem that the electrical design has shown the same rapid advance as the mechanical design, with the result that operating power factors of 30 and 40% are the rule rather than the exception on welder sizes above 100 or 200 kva. There are some large welders, particularly well-designed electrically, with power factors between 60 and 70%, and it is hoped that with more emphasis being placed upon the electrical design, a greater percentage of the new machines will have power factors of this order.

Too much significance cannot be placed upon good electrical design with resulting high-power factors, especially in the large size units where maintaining a good supply voltage involves special plant distribution facilities. Considering a typical installation, a welder with a power factor of 30% will cause over twice the voltage drop in the power supply as one operating at 60% and producing the same weld. In other words, for a given voltage drop twice as large a welder can be served if the power factor is 60% instead of the exceedingly common figure of 30%.

It is true that high power factor in itself means nothing if it is accomplished at the expense of increased resistance losses in the secondary of the welder circuit. Reduced reactive losses are the real goal which, if achieved, will result in a machine of high-power factor. The more the users of resistance welders insist upon high power factor and efficient machines, the easier it will be for them to provide an economical electric supply for operating them. Money spent in improved design will be repaid many times over in savings in expenditures for transformer capacity and bus construction.

Plant Distribution

The average plant electrician, due to lack of experience with welder load, is handicapped when called upon to lay out and install a low voltage distribution system for serving resistance welders throughout a plant. Accepted rules and methods upon which he might base the design may provide a layout excellent for handling ordinary light and power loads but will usually prove utterly inadequate and ineffective if used for welding loads.

First, the load is single-phase and of such intermittent nature as to make any sort of satisfactory balancing on the three phases, such as is ordinarily done with single-phase lighting loads with the view of getting a balanced three-phase load, utterly out of the question. Second, the effective heating upon which the current carrying capacity of the distribution system should be based is so small that in practically all cases temperature rise due to load current can be neglected and all efforts be concentrated on the regulation features of the system to produce a layout having minimum reactance.

If provision must be made for only one welder, good regulation is not necessarily essential, although it is certainly desirable. Practically all welding transformers have a 100% range of voltage taps and different voltage drops can be compensated for by operating on the proper tap. Once the proper tap is selected for a given supply

system regulation, it should not need to be changed. However, where a group of welders are operating from a common supply source with the possibility of two or more machines operating at the same instant, it becomes necessary to design for low regulation in order that cold welds will not result when more than one welder happens to operate at the same time. Just how much regulation is permissible is a matter of opinion based upon actual operating experience. Discussing this point with several plant engineers, it seems that about 10 to 15% total drop, i.e., the total drop up to the point where two or more welders may be affected, is a reasonable value upon which to base a design.

The first step in laying out a suitable system is the establishing of this maximum allowable per cent regulation. If, for instance, it is decided that 15% regulation shall not be exceeded, the various parts of the system can be proportioned so that the total drop for the largest welder will not exceed that figure. Next, determine from the power company how much regulation there will be in the power system up to the customer's point of service. This will vary considerably for different locations and no average figures can be given. The remainder of the 15% allowable can be taken up in transformer and bus drop. The transformers should always be located as near the welders as possible, but in some cases it becomes necessary to have bus runs several hundred feet in length. The type of bus construction used will depend upon the distance and the economic balance between bus cost and transformer cost in keeping the voltage regulation within allowable limits.

Practically all welders are single-phase in operation and where possible should be balanced on the three phases of the power source if they constitute an appreciable part of the plant load. However, it is essential from the standpoint of voltage drop that the balancing or grouping be accomplished on the high voltage side of the step-down power transformers. For instance, if there are three or more groups of welders in a plant, each group fed by separate transformer banks, the transformers should be connected in single-phase groups rather than in three-phase combinations. A given welder fed from a bank of three transformers connected in delta or wye will cause twice the voltage drop through the transformers as when fed from the same three transformers connected in parallel on the same phase. Thus, for the same voltage regulation there need be only one-half the investment in transformers if they are connected single-phase and the load balance obtained by balancing groups of welders rather than balancing the individual welders on separate phases.

In welding transformers, the limit of permissible voltage drop is usually reached long before the limit of permissible temperature rise. For this reason, it is essential that such transformers be purchased with as low impedance as practicable. Obviously too low an impedance cannot be specified without materially increasing the cost of the transformer and probably $3\frac{1}{2}$ to 4 per cent is as low as can be obtained without an undue increase in cost. A voltage of 480 is preferable to 240 where welders of any appreciable size must be served.

Figure 2 shows the per cent voltage drop per 1000 amperes of welding current at 40% power factor, 480 volts, for various sizes of transformers with impedances ranging from $3\frac{1}{2}$ to 8%. A 4% impedance, 1000-kva. transformer is for all practical purposes as good for a given welding service as an 8%, 2000-kva. transformer, and will cost much less. Using this chart it is a very simple matter to select a size of transformer of a given impedance which will keep the voltage drop through the transformer within the desired limits.

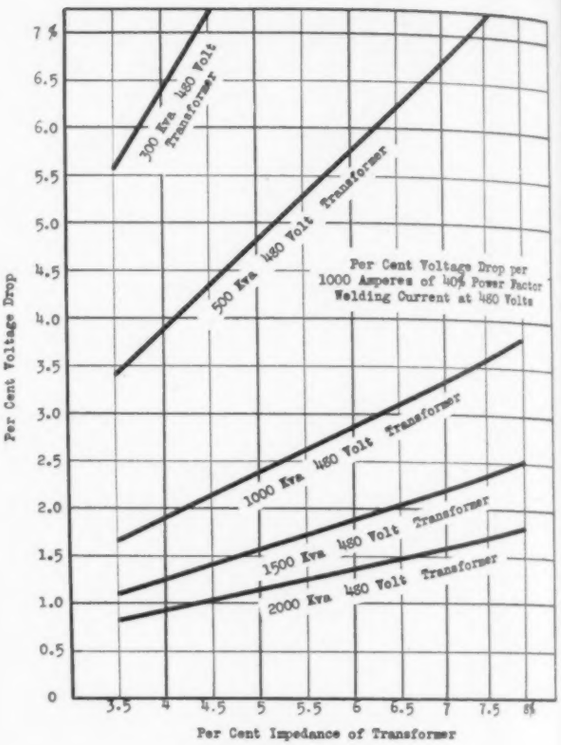


Fig. 2—Welder Transformer Regulation

A further reason for serving welders from single-phase transformer banks is the greater simplicity of construction for a low reactance single-phase bus as compared with a similar three-phase bus. Probably the simplest and cheapest bus construction consists of ordinary rubber insulated wire, taped together and either hung on racks or pulled in conduit. One disadvantage of such construction is the lack of facilities for easily tapping off connections for welders throughout the bus length. When only two or three welders are to be served at a common location at a considerable distance from the supply transformer, this construction is cheap and effective.

Figure 3 shows the per cent voltage drop per 1000 amperes of welding current at 40% power factor, 480 volts, for various types of bus construction in lengths from 100 to 400 feet. With this chart it is a relatively simple matter to select a type of bus which will keep the regulation within the allotted limit for the largest size welder. The chart values, calculated from basic inductance formulas, were checked by test measurements of actual operating installations.

A bus construction which permits easy tap connections at frequent intervals along its length is desired in production plants where manufacturing methods are continually changing. With a welder bus extending the full length of a plant, welders can be moved about to meet changing conditions without great trouble.

A satisfactory type of construction consists of four $\frac{1}{4}$ in. x 4 in. copper bars mounted in micarta blocks and interspaced with micarta strips to form an interlaced bus with the bars on one-inch centers. Bolted tap connections are easy to make on such a bus, and welders drawing 4000 to 5000 amperes at 480 volts can be served at distances several hundred feet from the nearest transformer bank. Several such buses have been operating in various Detroit plants for several years and have proved very satisfactory.

Where greater distances must be covered or less drop

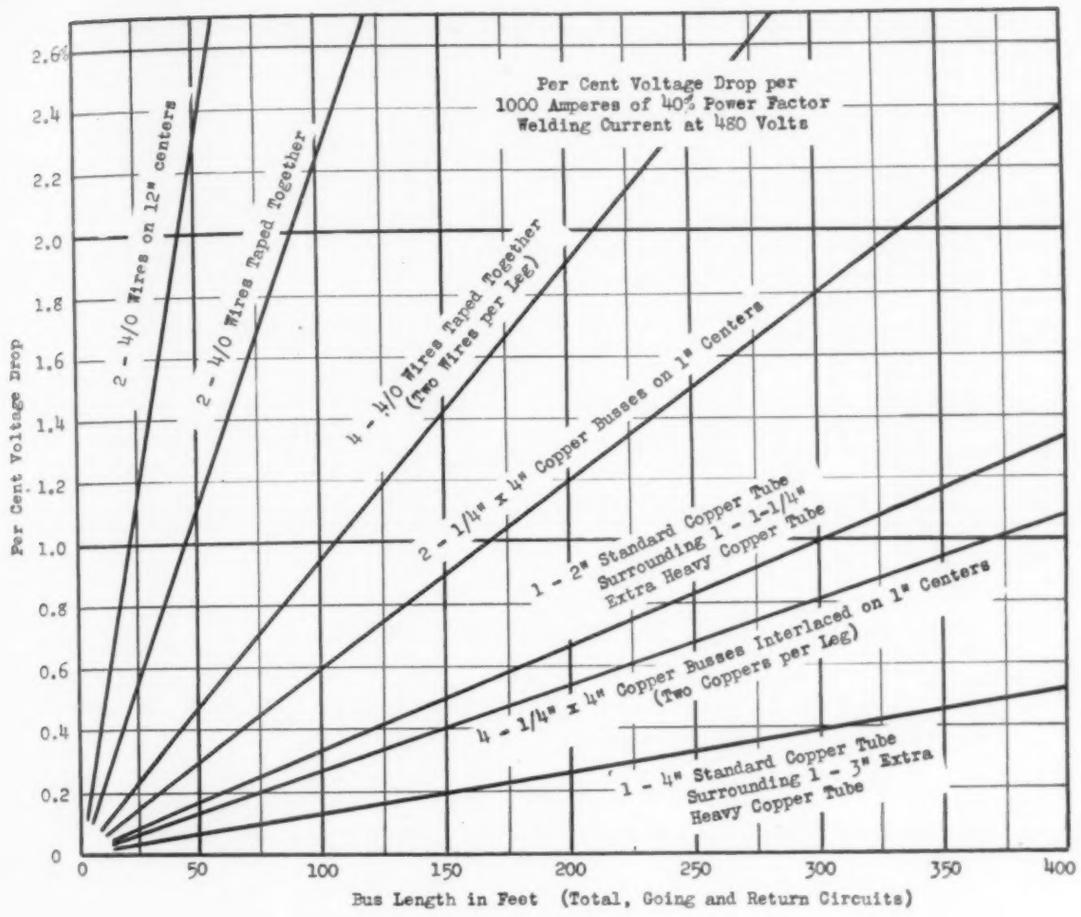


Fig. 3—Welder Bus Regulation

allowed, concentric tubing can be used to advantage. One installation using a 3-inch extra heavy copper tube inside of a 4-inch standard tube is being used for serving welders at distances in excess of 500 feet from the supply transformers. A micarta tube forms the insulation between the two conductors and the outer tube is grounded so that no bus insulators are required. The only special fitting required is at the tap points which are provided at 6-foot intervals. No great amount of experience has been had with this tubular type of bus, a new development of one of the leading automobile manufacturers who have just finished a complete installation for use during the current production season. There are over a thousand feet of the main bus of the large tubing with numerous branches using 1 $^1/_4$-inch extra heavy tubing surrounded by 2-inch standard tubing. The bus details for the joints, taps and branch connections are exceptionally well-designed and there is every reason to expect a good operating record. From Fig. 3 it is seen that the 3-inch–4-inch concentric tubular bus has the lowest voltage drop of any of the types of construction shown.

As an illustration a typical design will be worked out. A plant desires a welder distribution system to be laid out for serving 10 welders, the largest of which is a 500-kva. flash welder drawing 1450 kva. during the upset. The welder bus shall be capable of serving welders at any location throughout the length of a 400-feet production aisle with the transformer located at one end. It is decided that 12% drop is the maximum that can be tolerated and the design should be based on this value.

1. The power company is asked to determine the expected voltage drop in the power system up to the customer's connection point for a welder swing of 1450 kva. In this particular case the drop amounts to 4.2% which leaves 12−4.2% = 7.8% allowable drop for the bus and transformer.
2. From Fig. 2 a suitable transformer size is selected. 1450 kva. at 480 volts is 3000 amperes. It is assumed that new transformers are to be purchased and that transformers of 4$^1/_2$% impedance can be obtained. From the chart there is 2.15% drop per 1000 amperes with a 1000-kva. transformer. For 3000 amperes this is 6.45%, which is excessive, as it does not allow sufficient margin for bus drop. Perhaps two 1000 transformers in parallel is a logical selection, giving a drop of 3.23%, leaving 7.8−3.2% = 4.6% drop for the bus.
3. From Fig. 3 it is seen that either the four $^1/_4$-in. x 4-in. copper bar interlaced bus or 3–4-inch concentric tube bus must be used. The interlaced bus for 400 feet, 1000 amperes, gives 1.1% drop which is 3.3% for 3000 amperes.

The sum of the three parts of the total regulation is 4.2 + 3.2 + 3.3 = 10.7% or slightly less than the limit allowed.

An economic study of bus cost versus transformer cost should be made to determine at which point a given reduction in regulation can be made for the least invest-

ment. Sometimes transformer capacity can be increased to advantage while in other cases it proves more economical to select a more expensive bus construction.

Conclusions

1. The ratio of welder energy consumption to connected load is so much less than for other types of load that possible expenditures necessary for serving the load cannot be made on the basis that the expected earnings will justify the capital expenditures in anywhere near the same proportion as for general power load.
2. The ordinary rotating induction watt-hour meter functions with reasonable accuracy when metering energy used by resistance welders.
3. The power company's usual method of providing satisfactory resistance welding service consists essentially of finding a low-cost point of service of ample capacity to keep the voltage flickers within specified allowable limits. This is not generally difficult in dense industrial areas, but at other locations it may be necessary for the customer to provide either a power line extension for serving the welder load, or a motor generator set for shielding the power system from the welder disturbance.
4. The customer's problem consists of providing a low reactance distribution system of reasonable cost. This usually requires an interlaced or concentric bus of special construction and the use of single-phase low reactance transformers.
5. The welder manufacturer should be concerned with the electrical design of large resistance welders with efforts extended toward lower reactive losses and resultant higher operating power factors. There have been frequent examples in the past of bad electrical design which have further increased the cost of providing adequate service.

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WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

A Message from Our President

To the Members of the
AMERICAN WELDING SOCIETY:

Within a few days after the October Journal comes to you, we will be on our way to Atlantic City for the Convention. The committee and Warner Hays are arranging a presidents' reception for Sunday afternoon, October 17th. This affair is to give you the opportunity to meet the old and new presidents and over a cup of tea—isn't that something for a lot of welders—tell them just what you have in mind. Phil Lang has broad shoulders and can take it, and inasmuch as I will soon be relegated to the rear ranks, I'll spur you on in your criticisms or suggestions, all of which I know will be constructive. This reception is as much for the ladies as the men, and I hope you will bring them. It will give them the opportunity to meet the committee who will look after them during the week, also to meet Miss Kelly, Mrs. Lang, Mrs. Gibson and the wives of a lot of old timers who have come to look on the Annual Convention as theirs as much as their husbands.

This annual meeting will be unusual from many standpoints. I know you will be thrilled at the reports on the progress we have made this year and the prospects for next year. There just isn't any reason why, as a technical society dealing with the liveliest engineering and production problem facing American industry today, we shouldn't be making history. We have something industry needs, something industry is using to its advantage. There is every reason for a strong, alert, progressive organization to further the interests of the art and science of welding. Industry, engineering, production and education recognizes this need and their support and encouragement have made this year's progress possible.

Mr. Hays' program for new chapters to be established this fall will keep him on the jump, contacting local welding interests throughout the middle west and south. I have arranged, at considerable sacrifice to my own business, to visit many of the cities where he expects shortly to establish chapters. The growing list of local sections and the large increase in membership we shall have to report at Atlantic City will convince you that your National Society and a large number of members have done a creditable job this year.

Isn't Mr. Spraragen doing an excellent job with the Journal? Just pick up a copy of a year ago and compare it with the October issue. With a little larger advertizing revenue, you won't be able to recognize the old magazine in its new makeup. The Journal is the tie between you and the National Society throughout the year, and we want to give you a larger, better, more attractive copy every issue.

In many ways I regret having to step aside with the closing of the Convention. I have thoroughly enjoyed trying to do something constructive, which although but a start, will lead, under other management, to establishing the AMERICAN WELDING SOCIETY as an outstanding scientific organization. Personal problems permitting, it would have been a real pleasure to have carried on another year, provided you wished me to, but the more I see of Phil Lang, the more I am convinced that the Nominating Committee picked a strong candidate who will make history for the Society. I know only too well the assistance a president needs to accomplish results, and I shall give him all the help I can—I know you will too.

I shall probably not have the opportunity to see and to thank all of you personally for your splendid cooperation during my year in office, but I want you to know that I appreciate it. Whatever we have accomplished has been because of your help and cooperation. I am truly grateful to you, and although the man at the top generally gets the credit for results accomplished by any organization, I recognize that the credit really belongs to the rank and file.

See you at Atlantic City! Don't leave the wife at home. By the way, won't you sign up that new member before October 18th?

A. E. GIBSON

Welding Courses

The opening of classes on Tuesday, September 7th, in all Departments of the Milwaukee School of Engineering, marks the beginning of the thirty-fifth school year.

Many new courses are being offered during the 1937–38 academic year, particularly by the Welding Institute of the school. Courses in Welding Fabrication and Advanced Metallurgy, for which there have been many requests, are to be taught in conjunction with other courses in Welding. All of these courses are available in both the day and evening classes.

Foundrymen's Association

The American Foundrymen's Association in cooperation with the State University of Iowa and the Quad City Chapter of A. F. A., is holding a two day conference at the University, Iowa City, October 29 and 30, 1937. This is the second annual foundry conference devoted to various phase of foundry practice.

The committee of the Quad City Chapter which has developed a program in cooperation with A. V. O'Brien, State University, consists of T. J. Frank, Frank Foundries Corp., Moline, Ill.; Horace Deane and E. A. Gullberg, Deere & Co., Moline, Ill.

United States Civil Service Examinations

SENIOR ENGINEER, $4600 A YEAR
ENGINEER, $3800, A YEAR
ASSOCIATE ENGINEER, $3200 A YEAR
ASSISTANT ENGINEER, $2600 A YEAR

Applications must be on file with the United States Civil Service Commission at Washington, D. C., not later than the following dates—(*a*) *October 11, 1937*, if received from States other than those named in (*b*), below. (*b*) *October 14, 1937*, if received from the following States: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming.

The United States Civil Service Commission announces open competitive examinations for the positions named above. Vacancies in these positions in Washington, D. C., and in the field, and in positions requiring similar qualifications will be filled from these examinations, unless it is found in the interest of the service to fill any vacancy by reinstatement, transfer, or promotion. The salaries named above are subject to a deduction of $3\frac{1}{2}$ per cent toward a retirement annuity.

15th Annual Convention American Institute of Steel Construction

The 15th Annual Convention of the American Institute of Steel Construction will be held on October 26–29 at the Greenbrier Hotel, White Sulphur Springs, W. Va. Members of the AMERICAN WELDING SOCIETY are cordially invited to attend this meeting.

Welding

No Substitute for Skilled Workman

(*Editorial Appearing in Sept. 1937 Issue Railway Engineering & Maintenance*)

No phase of track maintenance has undergone a more marked change during the last twenty years than the maintenance of frogs and crossings. As a matter of fact, it could almost be said that except for the tightening or replacement of bolts, frogs and crossings were subjected to little real maintenance two decades ago. About all that could be done with them when they were worn beyond allowable limits was to take them out of track for rebuilding or scrapping. Fusion welding has changed this picture—special trackwork is now retained in track for service periods undreamed of a few years ago.

However, in the light of what is now known about the requirements of good workmanship in welding, or of the difference between the results to be expected from correct and incorrect methods of doing the work, it is easy to understand why many of the early efforts to apply fusion welding in this field were attended by indifferent success and frequent failures. The reason is obvious; this work represented the pioneer application of a new process with untried materials and unskilled workmen. Increased metallurgical knowledge, improvement in the quality of welding rods and the knowledge gained by the process of trial and error have been responsible for the creation of a technique in the repair of trackwork by welding that will assure good work, if rigidly observed.

This technique embraces discrimination in the selection of materials, the application of rather well-defined rules of procedure and criteria governing the decision as to whether a given piece of repair work should or should not be undertaken. But even more important than any of these, it calls for welding skill. Unlike blacksmithing, in which knowledge and skill have been passed from master to apprentice since time immemorial, fusion welding has been evolved in a few years by the joint application of theory and practice, but the fact still remains that there is no substitute for the skill of the craftsman.

Movie Film

Having completed a two-week long, high-speed production schedule at Gary Works of the Carnegie-Illinois Steel Corporation, the film crew shooting America's first technicolor short industrial feature film moved on to South Chicago yesterday to photograph the electric furnaces and beam mill at South Works. The troupe of 21 Hollywood camermen, technicolor experts, electricians and other technicians are making the picture for the United States Steel Corporation. Twenty steel plants will figure in the completed film, which is being produced by Hollywood Director Roland Reed.

Following a schedule of several days at South Works, the photographers will go to Joliet to cover the new rod mill of the American Steel and Wire Company and will complete their Chicago schedule at the American Steel and Wire plant in Waukegan.

The film company has been on location since August 14th, beginning at the Iron Range at Hibbing, Minnesota. At Hibbing, miners of the Oliver Iron Mining Company were filmed as they unearthed the raw ore. The giant ore boats of the Pittsburgh Steamship Company fleet were photographed as they were loaded with ore at Duluth, and as they unloaded the ore at the harbor of Gary Works.

Actors in this picturization of the romance of steel are all employees of United States Steel Corporation subsidiaries. No professional actors are used and each man is shown doing his everyday work. Three versions of the picture are being produced. Two of these are in technicolor and sound and will be distributed to theaters, clubs, engineering societies and other groups. The third film is a long black and white version for educational uses.

When the filming at Chicago district plants of United States Steel Corporation subsidiaries is completed, the movie troupe will leave for Cleveland and Pittsburgh where the actual filming of scenes will be completed.

McKay Company to Make Electrodes

The McKay Company, best known for its outstanding success in the manufacture of tire chains and industrial chains, and in recent years for its output of highly modern metal furniture, has just announced the establishment of a new division for the making of shielded-arc welding electrodes. Itself one of the world's largest users of electric welding and its processes, the company is thus only extending its activities in a field to which it brings a fund of practical experience.

The McKay technical staff has been at work for over two years in developing the formulas and procedures by which coatings are made and applied to McKay rods, and the aid of a leading independent research staff is being used to supplement such efforts.

Welders' Templates

By F. W. BOLLMAN*

The average welder has some method of laying out the pattern for a welded pipe joint, but it is inconvenient to stop welding and do the necessary drafting. This is no longer necessary, for all of this work has been done. It is merely a question of having a set of templates and picking the one you want for the job.

The patterns include the tees, 45 degree ells, 90 degree ells, three piece ells, laterals, round ends, swedge nipples, Y's and split bull plugs for 1-inch to 12-inch nominal Inside Diameter Pipe, and several sizes of casing.

Light-Gage Steel in Housing

An address on "Light-Gage Flat-Rolled Steel in Housing" will be presented by F. T. Llewellyn, Research Engineer, United States Steel Corporation, at the Annual Convention of the American Institute of Steel Construction, White Sulphur Springs, W. Va., October 1937. This address has been preprinted in an unusually attractive form. Although welding is not particularly mentioned because this deals with systems rather than with methods of fabrication, most of the systems lend themselves to the use of welding.

* Chemical Engineer.

A. S. T. M. Meeting

The next Annual Meeting of the A. S. T. M. will be held in Atlantic City, June 27 to July 1, 1938. The Spring Regional Meeting and Group Committee Meetings will be held in Rochester, N. Y., during the week of March 7th.

During the convention in Atlantic City next June, the AMERICAN WELDING SOCIETY, through its Welding Research Committee, expects to arrange a joint symposium on the subject of Impact Testing with particular reference to welding.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-241. Welding Engineer, Supervisor, Inspector. 10 years' experience in welding procedure, shop methods, design, physical metallurgy, qualification tests and training of apprentices. Available January 1, 1938.

POSITIONS VACANT

V-82. Engineering Teachers. We are in need of two teachers in our engineering shops. A two-year technical course has been initiated here so that in addition to regular engineering shop courses, this department will offer the practical work in the trade courses in machine shop and in welding. Some criteria for these men and their qualifications are:

1. Age: Not over forty, not under thirty.
2. Experience: Four to six years in trade. Union card or welding certificate preferred.
3. Education: Mechanical or Industrial Engineering degree desired. Bachelors degree required.
4. Teaching Experience: Not absolutely required, but is desirable.
5. Character: Must be clean morally and must possess high ideals of morality and ethics.
6. Personality: For the position as machine shop teacher, a good ability to meet students and develop a helpful relationship with the machine industry of the state.

   The welding teacher will be expected to develop close relationships with the welding industry by visits to plants, holding short courses and conferences, and acting as consultant for solving welding problems.

The salary will be from $2000.00 to $2500.00.

SECTION ACTIVITIES

CHICAGO

The first meeting of the Season of the Chicago Section was held on Friday night, September 17th, at the Skytop Restaurant, Medical and Dental Arts Building. The meeting was preceded by a dinner with an attendance of 54 at the dinner and a total attendance at the meeting of 106. Tom Jones, Chairman of the Section, presided at the meeting, and was followed in order by Warner S. Hays, Managing Director of the AMERICAN WELDING SOCIETY, and Mr. Leon C. Bibber, of the Carnegie-Illinois Steel Company. Mr. R. S. Kenrick, the new Editor of *The Welding Engineer* was introduced by Chairman Jones. The meeting was devoted to a Symposium on the new Welding Symbols and the general discussion brought out many enlightening facts regarding the Symbols, as well as the increased activity of the AMERICAN WELDING SOCIETY.

DETROIT

The following officers of the Detroit Section were elected for the year 1937–1938.

Chairman—Vaughan Reid
Vice-Chairman—D. H. Corey
Secretary-Treasurer—H. P. Doud
Executive Committee, 1937–1939—J. D. Tebben, F. E. Foote

The other two members of the Executive Committee, whose terms expire in 1938, are Walter Anderson and Joe Calley.

The first meeting of the season will be held on October 6th, in The Detroit Edison Company Auditorium. The Taylor-Winfield Company is furnishing the speaker and several reels of moving pictures showing applications of welding, both arc and resistance. in industry.

KANSAS CITY

The first meeting of the fall season was held on September 27th, Kansas City Power and Light Co. Building. Mr. Frank C. Hutchison, Manager of Process Service, The Linde Air Products Co., addressed the meeting on "Fabrication of Structural Members and Machine Parts." An informal discussion followed Mr. Hutchison's talk.

LOS ANGELES

A meeting of the Executive Committee of the Los Angeles Section was held at the residence of Mr. T. C. Smith on September 15th. Mr. K. V. King, Divisional Vice-President being in town was a welcome visitor to the meeting.

Discussion took place as to the advisability of sending a representative of the Section to the Annual Convention of the Society in Atlantic City this month. It was decided to send the Chairman, Wayne Howard, as the representative of the Section. A Convention Committee, consisting of C. P. Sander, P. D. McElfish and Joe Killian, was appointed to provide an alternate if necessary and to handle the ways and means of financing the trip.

The possibility of another Educational Course next year, similar to the one presented this spring, was discussed and the committee felt that the success of the past course justified presenting another course next year, and the Chairman is to appoint an educational committee to devise ways and means and the subject of the new course.

Due to transfer of Chester T. Mott, Membership Committee Chairman, to the East, Mr. P. D. McElfish was appointed to that position.

Russell Graves, Secretary and Treasurer, is being transferred to Oleum, California, and J. C. Gowing was appointed as Secretary-Treasurer for the remainder of the term.

The matter of programs for the regular meetings was discussed and it was decided to proceed as in the past, that is, to present one technical paper and one general paper at each meeting. The Committee also instructed the Secretary to have notices of regular meetings mailed to all Pacific Coast Sections of the different Societies.

MILWAUKEE

The following officers and directors of the Milwaukee Section were elected:

Chairman—K. L. Hansen
Vice-Chairman—H. F. Falk
Secretary-Treasurer—J. J. Chyle

The following directors were elected:

F. O. Volz — S. H. Smith
J. Shodron — G. F. Meyer

The other directors finishing their second year term:

E. Behling — H. Quartz

NORTHERN NEW YORK

The following officers and directors of the Northern New York Section were elected for 1937–1938:

Chairman—W. F. Hess
1st Vice-Chairman—F. H. Miller
2nd Vice-Chairman—R. W. Clark
Secretary-Treasurer—G. A. Ross
Director at Large (Section Rep. on Board)—L. R. Leveen
Directors: R. T. Gillette — R. L. Browne
A. G. Cochrane — E. J. Myers
M. Unger — T. R. Lawson

NORTHWEST

The Northwest Section of the AMERICAN WELDING SOCIETY was formally organized at an enthusiastic meeting, Wednesday July 28, 1937, at the Minnesota Union University of Minnesota. The speaker of the evening was L. A. Dills, Senior Engineer of the State of Minnesota Department of Highways, who gave a most interesting discussion on "Welders' Qualifications."

Officers and members of the executive committee were elected to serve until the first annual meeting in May 1938.

The September meeting of the Northwest Section was held on Monday, September 27th, at the Minnesota Union, University of Minnesota. The speaker of the evening was Mr. Harry Boardman, Chief Engineer, Chicago Bridge & Iron Co., who discussed "Fabrication of Tanks in the Shop and in the Field."

PHILADELPHIA

"The Experimental Background of Welded Design" was the subject of Mr. Leon C. Bibber of the Carnegie-Illinois Steel Corporation, paper presented on Monday evening, September 20th in the Auditorium of the Engineers' Club.

PITTSBURGH

The opening meeting of the Pittsburgh Section for the 1937–38 Season will be held Wednesday night, October 13th in the Blue Room of the Roosevelt Hotel. The principal speaker for the evening will be Mr. A. E. Gibson, President of the AMERICAN WELDING SOCIETY and Executive Vice-President of the Wellman Engineering Company. Mr. Gibson will speak on what the AMERICAN WELDING SOCIETY has done this past year nationally, and will also give a talk on "The Use of Rolled Steel in Welded Construction." Lantern slides will be used to illustrate the talk.

The Pittsburgh Section has advised of the election of the following Officers:

Chairman—Leon C. Bibber
Vice-Chairman—J. O. Rinek
Secretary—J. F. Minnotte
Representative on National Board of Directors—W. W. Reddie

The new officers will preside at the October 13th meeting.

ST. LOUIS

The opening meeting of the 1937–38 Season of the St. Louis Section was held at the Moose Hall, 4005 Westminster Place on Friday, September 17th, at 8:00 P.M. "The Advancement of Welding in Industry" was presented by F. C. Fantz, Vice-President of the Midwest Piping & Supply Co.

SAN FRANCISCO

The September meeting of this Section was held on the 24th at the Athens Athletic Club, Oakland. A sound motion picture on the production of Stainless Steel, furnished through the courtesy of the Republic Steel Corporation was shown, which was followed by a preliminary discussion and a lecture by a qualified expert on the subject.

It is planned for the October meeting to have a paper and discussion on welded construction.

Mr. T. R. Rooney, Vice-Chairman of the Section and Chairman of the Program Committee, promised many other interesting programs for the season and included among them will be several plant visitations in the shops of some of the larger firms in the vicinity of the San Francisco Bay.

Plans are now being made for the formation of a Prize Paper Committee to work out the rules and regulations for a Prize Paper Contest to be held among the various university students within a certain designated area to be determined by the Committee. A substantial cash prize together with a medal and a free membership to the local chapter of the AMERICAN WELDING SOCIETY will be given the winner, the entire contest to be sponsored by the San Francisco Section of the AMERICAN WELDING SOCIETY.

AMERICAN WELDING SOCIETY

OFFICERS 1936-37

President, A. E. Gibson
Senior Vice-President, E. R. Fish
Managing Director, Warner S. Hays
Treasurer, C. A. McCune
Secretary, M. M. Kelly
Technical Secretary, W. Spraragen

Divisional Vice-Presidents

J. H. Zimmerman, New York & New England
R. D. Thomas, Middle Eastern
T. C. Smith, Pacific Coast
H. C. Boardman, Middle Western
E. E. Dillman, Southern Division

CHAIRMEN AND SECRETARIES OF SECTIONS AND REGULAR MEETING DATES

To Members
AMERICAN WELDING SOCIETY

When in any city where sections of the Society are located—try to attend the meetings if they happen to be held during your visit. This will widen your contacts in welding and enable you to gain an interchange of experience with others in similar lines of business. If no regular meeting date is given on the above list of sections—telephone the Secretary and he will gladly tell you and help in any other way if you want local information on welding users or problems.

W. S. HAYS
Managing Director

BIRMINGHAM — 3rd Fri.
CHAIRMAN—E. E. MICHAELS, Chicago Bridge & Iron Co., P. O. Box 277
SECRETARY—J. E. DURSTINE, Lincoln Elec. Co., 505 No. 22nd St.

BOSTON — Middle Fri.
CHAIRMAN—P. J. HORGAN, General Electric Co., Lynn, Mass.
SECRETARY—P. N. Rugg, Boston Edison Co., 39 Boylston St.

CHICAGO — Last Fri.
CHAIRMAN—TOM JONES, 8244 East End Ave.
SECRETARY—L. C. Monroe (Webster 7134), The Welding Engineer, 608 So. Dearborn Ave.

CLEVELAND — 2nd Wed.
CHAIRMAN—E. R. BENEDICT, Contract Welders, Inc., 2445 E. 79th Street
SECRETARY—E. T. SCOTT, Cleveland School of Welding, 2261 E. 14th St.

DETROIT — 1st or 2nd Fri.
CHAIRMAN—VAUGHAN REID, City Pattern Works, 1165 Harper Ave.
SECRETARY—H. P. DOUD, General Electric Company, 700 Antoinette St.

HAWAII
CHAIRMAN—E. E. HEACOCK, Hawaiian Gas Products Ltd., P. O. Box 2454, Honolulu, T. H.
SECRETARY—R. L. MULLEN, Honolulu Iron Works Co., Honolulu, T. H.

KANSAS CITY — 3rd Mon.
CHAIRMAN—C. E. WOODMAN, Kansas City Bridge Co., 215 Pershing Rd.
SECRETARY—ALBERT W. ROTH, 1531 Broadway

LOS ANGELES — 3rd Thurs.
CHAIRMAN—WAYNE A. HOWARD, General Petroleum Corp., 2525 E. 37th Street
SECRETARY—J. C. GOWING, P. O. Box 186, Huntington Park, Calif.

MARYLAND — 3rd Fri. except April
CHAIRMAN—DR. J. W. MILLER, Reid Avery Co., Chesi & Cleveland Aves., Dundalk, Md.
SECRETARY—C. N. HILBINGER, Lincoln Electric Company, Baltimore, Md.

MILWAUKEE — 2nd Wed.
CHAIRMAN—K. L. HANSEN, Harnischfeger Corp.
SECRETARY—J. J. CHYLE, 2841 N. 51st St.

MONTANA — 1st Wed.
CHAIRMAN—HENRY F. C. RUMFELT, 701 Musselshell, Fort Peck
SECRETARY—ALLEN W. BATES, Apt. 4503D, Fort Peck, Montana

NEW YORK
2nd Tues. except when Joint Meeting is held
CHAIRMAN—R. W. BOGGS, Linde Air Products Co., 205 E. 42nd St.
SECRETARY—MILTON MALE, U. S. Steel Corp., 71 Broadway

NORTHWEST & ST. PAUL (Minneapolis) — 3rd Wed.
CHAIRMAN—H. J. KICHERER, American Hoist & Derrick Co., St. Paul, Minn.
SECRETARY—ALEXIS CASWELL, Manufacturers Assoc. of Minn., 405 Marquette Ave.

NORTHERN N. Y. — Last Thurs.
CHAIRMAN—W. F. HESS, Rensselaer Polytechnic Inst., Troy, N. Y.
SECRETARY—G. A. Ross, General Electric Co., Schenectady, N. Y.

WESTERN N. Y. — 3rd Fri.
SECRETARY—H. J. SCHLEIDER, Air Reduction Sales, 730 Grant St., Buffalo, N. Y.
SECRETARY—F. O. HOWARD, Am. Steel & Wire Co., 1403 Liberty Bank Bldg., Buffalo, N. Y.

PHILADELPHIA — Middle Mon.
CHAIRMAN—T. M. JACKSON Sun Shipbuilding & D. D. Co. Chester, Pa.
SECRETARY—H. E. HOPKINS, Arcos Inc., 401 N. Broad St.

PITTSBURGH — Middle Wed.
CHAIRMAN—LEON C. BIBBER, Carnegie-Illinois Steel Corp., Carnegie Building.
SECRETARY—J. F. MINNOTTE, Minnotte Bros., 1201 House Bldg.

PORTLAND
CHAIRMAN—G. C. DIERKING, Steel Tank & Pipe Co., P. O. Box 1899, Sta. F
SECRETARY—L. M. PICKETT, Steel Tank & Pipe Co., P. O. Box 1899, Sta. F

SAN FRANCISCO — Last Fri.
CHAIRMAN—N. F. WARD, University of Calif., Berkley, Calif.
SECRETARY, J. G. BOLLINGER, Air Reduction Sales, Park & Halleck Sts., Emeryville, Calif.

ST. LOUIS — 2nd Fri
CHAIRMAN—A. W. HARRIS, 2449 Milk Avenue, Alton, Ill.
SECRETARY—C. W. S. SAMMELMAN, 4359 Lindell Blvd.

YOUNGSTOWN (Ohio)
CHAIRMAN—CHARLES WATSON, Youngstown Welding & Engr. Co., Youngstown, Ohio
SECRETARY—C. A. WILLS, Wm. B. Pollock Co., Youngstown, Ohio.

SOUTH TEXAS
(Officers not yet elected).

OKLAHOMA CITY
CHAIRMAN (Pro-Tem)—O. T. BARNETT, Black, Sivalls & Bryson, Inc., Box No. 1377, Okla. City, Okla.
SECRETARY (Pro-Tem)—K. V. BANKS, Black, Sivalls & Bryson, Inc., Okla. City, Okla.

SECTIONS BEING CHARTERED

There is shown below Sections in process of organization and the name of the contact man in each locality. This contact man is either Chairman or Secretary of an active group interested in the formation and completion of Section Organization. Those members desiring to assist should communicate with these individuals.

ATLANTA, GA.
M. C. SNEAD, Link Belt Company, 1116 Murphy Avenue, S. W., Atlanta, Ga.

CANTON, OHIO
ROBERT M. WALLACE, The Griscom-Russell Company, Massillon, Ohio

CHATTANOOGA, TENN.
CHESTER T. RAYMO, Chattanooga Boiler & Tank Company, 1030 East Main St., Chattanooga

CINCINNATI, OHIO
W. W. PETRY, Cincinnati Milling Machine Co., Cincinnati, Ohio

MIAMI VALLEY (Dayton, Troy, etc.)
F. L. MEACHAM, 29 Wistaria Drive, Dayton, Ohio

DALLAS-FORT WORTH, TEXAS
E. E. DILLMAN, Wyatt Metal & Boiler Works, Dallas, Texas

FORT WAYNE, INDIANA
JAMES MCCLURE, Wayne Welding Supply Co., 513 East Wayne St., Fort Wayne, Indiana

INDIANAPOLIS, INDIANA
W. R. GARTEN, Sutton-Garten Company, 401 West Vermont St., Indianapolis, Ind.

LOUISVILLE, KY.
A. HURTGEN, Henry Vogt Machine Company, 10th & Ormsby Streets, Louisville, Ky.

MEMPHIS, TENN.
B. B. DRURY, JR., Modern Engineering Company, 238 South Front St., Memphis, Tenn.

NEW ORLEANS, LA.
A. H. GUILLOT, New Orleans Public Service Company, 317 Baronne St., New Orleans, La.

OMAHA, NEBRASKA
L. O. SCHNEIDERWIND, Omaha Welding Company, 1501 Jackson Street, Omaha, Nebraska

TOLEDO, OHIO
J. W. SHUGARS, The Lincoln Electric Company, 632 Spitzer Building, Toledo, Ohio

TULSA, OKLAHOMA
R. R. THOMPSON, Air Reduction Sales Company, Tulsa, Oklahoma